REPORT OF INVESTIGATION 21

GEOLOGY, GEOCHEMISTRY, AND MINERAL DEPOSITS OF THE BIG SALMON RIVER – GOOSE RIVER AREA NEW BRUNSWICK

MAP AREA S-27 AND PARTS OF R-27, S-26, AND T-26

(Parts of 21 H/6 and 21 H/11)

by

M.J. McLeod

A CANADA/NEW BRUNSWICK MINERALS AND FUELS SUB-AGREEMENT PROJECT FUNDED BY D.R.E.E. AND N.B.D.N.R.

MINERALS AND ENERGY DIVISION
DEPARTMENT OF NATURAL RESOURCES AND ENERGY
NEW BRUNSWICK

HON. MALCOLM N. MacLEOD, MINISTER

GOVERNMENT OF CANADA
REGIONAL ECONOMIC EXPANSION

GOUVERNEMENT DU CANADA
EXPANSION ECONOMIQUE RÉGIONALE

HON. M. COTÉ, MINISTER

Price $42.00
1987

ISSN 0077-8109

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This is a Federal-Provincial development project, funded under the Minerals and Fuels Subsidiary Agreement of the Canada-New Brunswick General Development Agreement by the Government of New Brunswick and the Canada Department of Regional Economic Expansion.

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NOTE: (R) indicates that the plate has been reduced from its original size. These geology maps (originally 1" to 1/4 mile) have been reduced to 1:20 000 scale.

ABSTRACT

The highly deformed Late Precambrian rocks in the Big Salmon River - Goose River area of southern New Brunswick are divisible into two distinct terranes that reflect different geological environments. The Cradle Brook-Walton Brook Fault, a major southward-directed thrust, separates the two terranes and is interpreted to represent, in part, the boundary between the Central and Eastern volcanic belts of the Caledonian Highlands. The rocks north of the fault reflect subaerial and, locally, subaqueous deposition whereas those south of the fault reflect marine deposition. The trace-element chemistry is consistent with a continental setting for the volcanic rocks in the north.

A pervasive cataclastic fabric is developed subparallel to bedding in most of the Cambrian and Precambrian stratified rocks and along the margins of the major intrusions. Locally, there is evidence for a pre-existing fabric. The absence of penetrative deformation in rocks of Carboniferous age and the presence of massive discordant diabase dykes of probable Siluro-Devonian age suggests that the cataclastic fabric may have developed during the Ordovician.

Granites, granodiorites, and monzodiorites of probable Precambrian age are common south of the Cradle Brook-Walton Brook Fault and along the northwestern margin of the map area north of the fault. Leucogranites and granites, that could be younger, occur south of the fault. Both suites are calc-alkaline but the latter is highly differentiated with high K_2O/Na_2O and Rb/Sr ratios and low TiO_2. Tholeiitic mafic intrusions occur throughout the project area.

Stream-, soil-, and rock-geochemical surveys and ground magnetometer surveys were conducted to test DIGHEM II electromagnetic anomalies and specific mineral occurrences in the project area. Copper and zinc sulphides, locally with trace amounts of gold, are most abundant south of the Cradle Brook-Walton Brook Fault.

RÉSUMÉ

Les roches très déformées du Précambrien tardif dont est constituée la région de Big Salmon River-Goose River, dans le sud-est du Nouveau-Brunswick, se répartissent en deux régions distinctes, lesquelles témoignent d'environnements géologiques différents. La faille de Cradle Brook - Walton Brook, un charriage majeur de direction sud, sépare les deux formations et constituerait, en partie, la frontière entre les ceintures volcaniques au centre et à l'est des hautes terres calédoniennes. Les roches situées au nord de la faille indiquent une accumulation subaérienne et, en certains endroits une accumulation subaquatique, tandis que celles au sud de la faille révèlent une sédimentation marine. La composition chimique des oligo-éléments coincide avec le cadre continental des roches volcaniques se trouvant dans le nord.

Une fabrique cataclastique pénétrative se développe subparallèlement à la stratification dans la plupart des roches sédimentaires du Cambrien et du Précambrien ainsi que le long des marges des intrusions majeures. Certains endroits démontrent les traces d'une fabrique qui aurait déjà existé. L'absence de déformation intrusive dans les roches du Carbonifère et la présence de dykes de diabase discordantes massives, datant probablement de la période siluro-dévonienne, laissent supposer que la fabrique cataclastique se serait développée durant l'Ordovicien.

Des granites, granodiorites et monozodiorites, datant probablement du Précambrien, sont répandus au sud de la faille de Cradle Brook-Walton Brook ainsi que le long de la marge nord-ouest de la région couverte par la carte se situant au nord de la faille. Des leucogranites et des granites pouvant être plus récents se trouvent au sud de la faille. Les deux séries sont calco-alcalines, toutefois la dernière se distingue fortement par son taux élevé en K_2O/Na_2O et en Rb/Sr, ainsi que par son faible taux en TiO_2. Des intrusions mafiques tholéiitiques ont été constatées partout dans la région étudiée dans le cadre du projet.

Des relevés géochimiques portant sur les alluvions, la terre et les roches, ainsi que des relevés du sol à l'aide d'un magnétomètre ont été effectués afin d'analyser les anomalies électromagnétiques DIGHEM II et les gisements de minéraux spécifiques dans la région couverte par le projet. Enfin, des sulfures de cuivre et de zinc, qui contiennent parfois des quantités petites d'or, sont très abondants au sud de la faille de Cradle Brook-Walton Brook.

INTRODUCTION

This report presents the results of geological, geophysical, and geochemical investigations that took place during 1979 and 1980 on Precambrian rocks in the Eastern Volcanic Belt of southern New Brunswick (Figure 1a). The project area is located in Saint John County about 20 km southeast of Sussex and includes map area S-27 and parts of map areas R-27, S-26, and T-26 (Figure 1b). This project was jointly financed by the New Brunswick Department of Natural Resources, Mineral Resources Division, and the Canada Department of Regional Economic Expansion. The purpose of the project was to produce detailed maps and assess the economic mineral potential of the area.

Fairly good access to the project area is provided by new logging roads from Sussex. Nearly continuous rock exposures are present along the coast of the Bay of Fundy and in deeply incised stream valleys that generally flow from north to south. Between stream valleys the topography is relatively flat (maximum elevation is 240 m) and outcrops are rare.

The project area is part of the Caledonian Highlands (Weeks 1957; Rampton et al. 1984) of southern New Brunswick, which constitutes a segment of the Avalon Zone (Williams 1978). The Avalon Zone comprises fragments of a once extensive land mass, formed in Late Precambrian time, that extends from the southern Appalachians through the Canadian Appalachians to Great Britain (Rodgers 1972; Rast et al. 1976). The rocks in this zone have been interpreted to have formed in either an ensialic island-arc or an extensional continental tectonic setting (see discussion by Giles and Ruitenberg 1977, pp. 1273-1274). Williams and Hatcher (1982) surmise that the Avalon Zone may be composite and comprised of several suspect terranes assembled in late Precambrian time.

Mineral deposits in the area are referred to in several old reports on the geology of New Brunswick (Bailey 1865; Bailey and Matthew 1872; and Ells 1907). Geological maps published by Ells (1880) and Kindle (1962) cover parts of the area. Barr and White (1986) and Barr (1987) mapped the area to the east in Fundy National Park. Some aspects of this report have been published (McLeod 1986). Some of the mineral occurrences were described by mining company geologists in assessment reports filed with the Department of Natural Resources and Energy. However, the first regional studies covering the entire project area are those of Giles and Ruitenberg (1977) and Ruitenberg et al. (1973, 1975, 1979).

A variety of techniques were used to evaluate the mineral potential of the project area. These included an airborne DIGHEM II electromagnetic survey and follow-up ground magnetometer and soil sampling surveys, a detailed stream sediment sampling survey, geological mapping, and grab sampling.

REGIONAL GEOLOGICAL SETTING

The rocks in the Caledonian Highlands have been considered as stratigraphic equivalents of the Coldbrook Group since the work of Alcock (1938). A summary of the nomenclature pertaining to the use of the name Coldbrook Group and Coldbrook Group equivalents is given by Alcock (1938) and Giles and Ruitenberg (1977). Kindle (1962) subdivided the Coldbrook Group equivalents into three major units: mainly felsic volcanics, mainly mafic volcanics, and a variety of detrital sedimentary rocks. He also delineated major granitoid and gabbroic intrusive bodies and units of Carboniferous and Triassic rocks in parts of the project area.

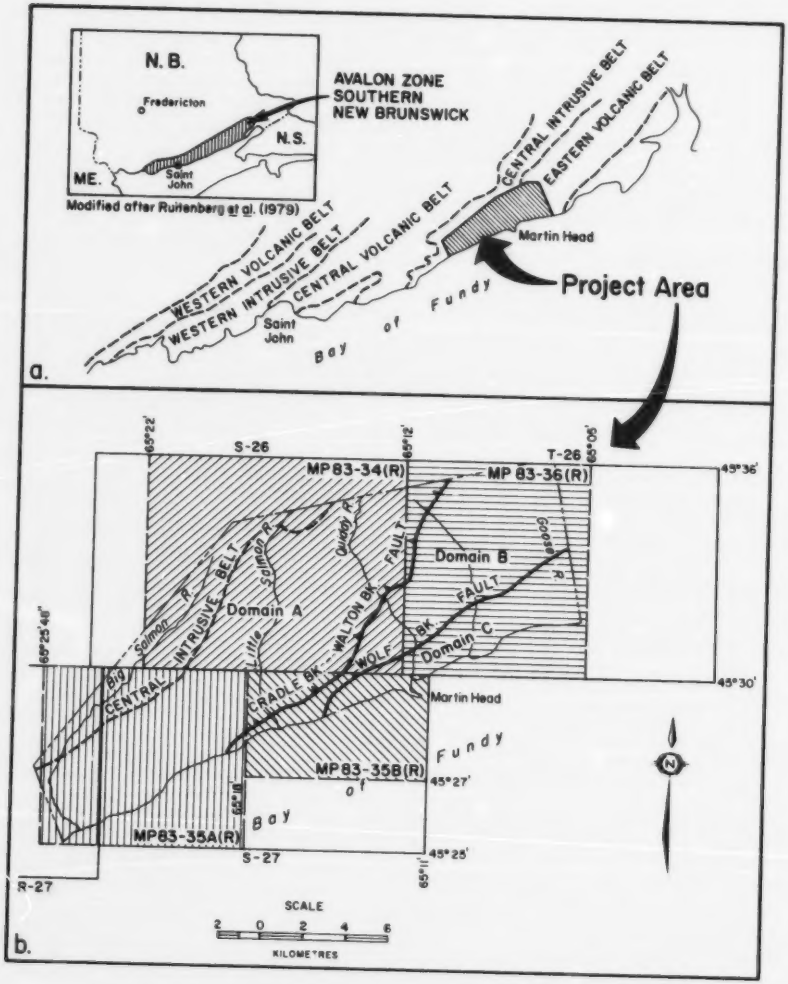


FIGURE 1. Location map and major tectonostratigraphic subdivisions (a) in the Caledonia area and (b) in the project area.

Ruitenberg et al. (1979) divided the Caledonian Highlands into several major tectonostratigraphic units (Figure 1a). Most of the project area is within the Eastern Volcanic Belt. A small portion in the northwest falls within the Central Intrusive Belt. Giles and Ruitenberg (1977) and Ruitenberg et al. (1977) delineated several major units including mafic flows and tuffs, felsic flows and tuffs, and a variety of detrital sedimentary rocks in the Eastern Volcanic Belt. They envisaged these rocks to have been deposited in a large basin on the flank of the extensive Precambrian landmass represented locally by their Central Volcanic Belt.

The grain-size parameters outlined by Wentworth (1922) are followed in this report for both volcanic and sedimentary rocks. The bed and lamination thickness parameters given by Reineck and Singh (1975) are used.

ACKNOWLEDGEMENTS

The author wishes to thank Shasta Abbott and Paul Lloyd for their able assistance in geological mapping. Jasper Sears, Tim Canam, and Wayne Hicks carried out the geophysical and geochemical surveys. M. Mazerolle and F. Kelly provided technical assistance. Sincere appreciation is also extended to S.R. McCutcheon and A.A. Ruitenberg for discussions of the geology and assistance in preparing this report. The manuscript was edited by S.A. Abbott, B.M.W. Carroll, L.R. Fyffe, J.B. Hamilton, S.R. McCutcheon, and A.A. Ruitenberg.

STRATIGRAPHY

The map area is divided by the Cradle Brook-Walton Brook Fault into two major lithostratigraphic sequences, and mappable units within these sequences are based on the relative proportions of dominant rock types (Figure 2). Most of the Precambrian rocks have been subjected to greenschist facies metamorphism and should consequently be considered metamorphic rocks. The units are summarized in the Table of Formations (Table 1). The establishment of detailed stratigraphy in the area, as a whole, is hampered by numerous intrusions, complex faulting, and intense cataclastic deformation that obscures primary depositional structures in most of the units. These factors, together with the repetitive nature of similar units, only permits the establishment of rather tentative stratigraphic columns for the area northwest of the Cradle Brook-Walton Brook Fault. Schematic stratigraphic columns for the area southeast of this fault can, however, be deduced by reestablishing the relative positions of fault blocks prior to strike-slip movement and then correlating units that are lithologically similar. Columns 1 to 5 (Figure 3) were prepared from sections located in the vicinity of; (1) the mouth of Little Salmon River, (2) the mouth of Wolf Brook, (3) Quiddy River south of Walton Brook, (4) Goose Creek, and (5) Goose River.

PRECAMBRIAN ROCKS

Coldbrook Group (Units 1 - 10):

A variety of intercalated fine- and coarse-grained, felsic and mafic tuffaceous rocks, basaltic flows, rhyolitic flows, and minor amounts of siltstone and sandstone (Units 1, 2, and 3) occur northwest of the Cradle Brook-Walton Brook Fault (Figure 2). An estimate of the total thickness of the units comprising this area could not be determined. The stratified rocks in this area are intruded by small bodies of granodiorite, gabbro, and diabase and are bounded on the north by two large intrusive bodies, the Bonnell Brook and Point Wolfe River plutons, that form part of the Central Intrusive Belt (Ruitenberg et al. 1979).

A variety of fine- and coarse-grained mafic and felsic tuffaceous rocks, mafic flows, hyaloclastites and hyalotuffs, detrital sedimentary rocks, and minor limestone (Units 4 to 10) occur southeast of the Cradle Brook-Walton Brook Fault (Figure 2). The presence of pyrite is ubiquitous in most of these rocks. The total thickness of strata southeast of the fault is at least 5000 m. The intensity of the cataclastic deformation in the tuffs of this area precludes reliable detailed descriptions of individual units. Mapping can be accomplished only by locating distinctive colour variations and rudimentary compositional variations in the tuffs, and by utilizing recognizable intervening sedimentary units as marker horizons.

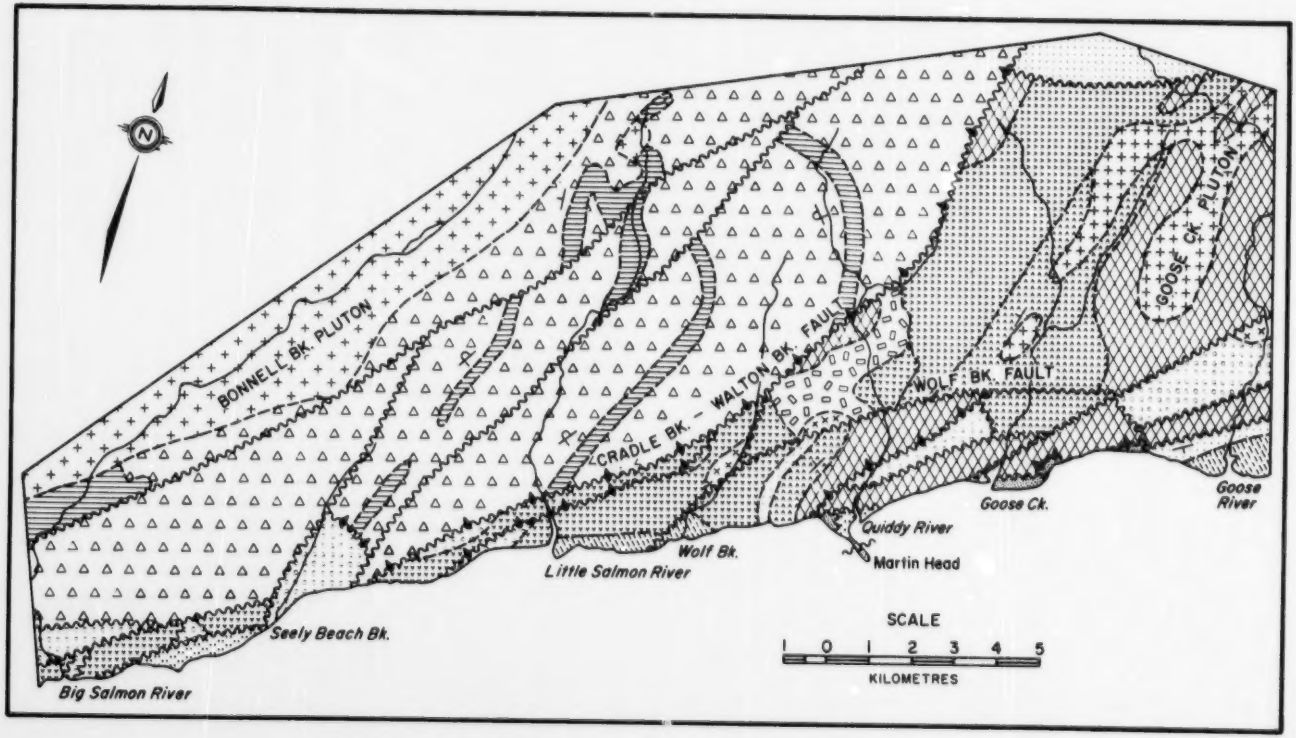


FIGURE 2. Generalized geological map of the project area.

NORTH OF CRADLE BROOK-WALTON BROOK FAULT

PRECAMBRIAN

Felsic and mafic intrusive rocks

Sedimentary rocks

Mixed felsic and mafic volcanic rocks

SYMBOLS

Fault

Thrust fault (dip direction indicated)

Geological contact

Bedding (known, overturned)

SOUTH OF CRADLE BROOK-WALTON BROOK FAULT

TRIASSIC

Sandstone, siltstone, and conglomerate

CARBONIFEROUS/OLDER

Fanglomerate, sandstone, limestone, gypsum, and basalt

CAMBRIAN

Conglomerate, quartzite, siltstone, and shale

PRECAMBRIAN

Leucogranite

Granite

Keratophyre

PRECAMBRIAN (cont'd)

Sedimentary rocks

Felsic volcanic rocks; agglomerate and limestone

Mafic volcanic rocks

Felsic volcanic rocks

Mixed felsic and mafic volcanic rocks

Mixed mafic volcanic rocks, felsic and mafic intrusive rocks

Unit 1: This unit consists of felsic lapilli tuff, coarse tuff with variable amounts of lithic fragments, vitric tuffaceous rocks, crystal tuffs, rhyolitic flows, and minor amounts of mafic volcanic rocks.

The felsic lapilli tuff and coarse tuff are variable in colour but red and buff hues predominate. They generally occur in thick (several tens of metres), fairly uniform sequences that are laterally continuous; beds, where preserved, are thick to very thick. Units in which fine or coarse grain sizes predominate are designated as Units 1a or 1b respectively. The rocks are poorly sorted and contain variable amounts of quartz, altered plagioclase, and felsic and mafic fragments that comprise up to 80% of the total volume. In Unit 1b, pebble-sized quartz fragments are commonly predominant, but felsic or mafic volcanic fragments are locally abundant. The matrix of these rocks consists of a microcrystalline mixture of quartz + muscovite $\pm$ chlorite.

Maroon vitric and crystal tuffs occur in relatively minor amounts within Unit 1. The crystal tuffs contain abundant medium-grained crystals of quartz and plagioclase that constitute up to 70% of the total rock. Vitric tuffs that occur west of the mouth of the Little Salmon River (in Unit 1a), contain coarse-grained spherulitic and recrystallized quartzose fragments that were probably derived from nearby rhyolitic domes. Both of these lithotypes have a very fine grained, completely recrystallized quartzose matrix.

The rhyolitic flows and massive felsic domes (Unit 1c) occur on Walton Glen Brook and Little Salmon River (Plates 83-35A[R], 83-35B[R]), and on old roads near the headwaters of Rapidy Brook (Plate 83-34[R]). They are maroon, fine-grained flows that commonly exhibit contorted flow lamination and generally occur in regular featureless layers, 1 to 2 m thick, oriented parallel to the regional tectonic fabric. The layering may represent separate lava flows, or may be a result of deformation. Spherulitic and axiolitic structures are apparent in thin sections and a few quartz phenocrysts are present. The overall outcrop pattern of Unit 1c rocks in the Little Salmon River area truncates the stratigraphy, suggesting that these rocks are intrusive domes.

Unit 2: This widespread unit consists of mafic lapilli tuff and coarse tuff with variable amounts of lithic fragments, mafic tuffaceous rocks, and mafic flows. The mafic tuffaceous rocks have similarities to their felsic counterparts; firstly, the grain size is variable and secondly, they occur in thick, fairly uniform, laterally continuous sequences with thick to very thick beds.

The fine-grained types (Unit 2a) are poorly sorted and contain variable amounts of altered mafic volcanic fragments, plagioclase, opaque minerals, and minor quartz. The matrix is composed predominantly of chlorite and recrystallized plagioclase. Some of these rocks exhibit fine, discontinuous laminations composed entirely of very fine grained, recrystallized plagioclase.

The coarse-grained tuffaceous rocks (Unit 2b) are poorly sorted and contain variable amounts of mafic and felsic volcanic debris, fragments and crystals of plagioclase, and minor quartz. The finer grained constituents of these rocks and the matrix are identical to Unit 2a.

Thick sequences (commonly 5 to 10 m) of altered mafic volcanic breccia (?) outcrop on the upper part of the Quiddy River in Unit 2, Plate 83-34(R). Large boulder- and cobble-sized mafic volcanic fragments (almost totally epidotized) occur in a medium- to fine-grained, highly altered mafic matrix. These large fragments exhibit no gradation in size within beds. A felsic rim of quartz and plagioclase generally encloses the large fragments.

TABLE 1

TABLE OF FORMATIONS

ERA	PERIOD	FORMATION OR GROUP	MAP UNIT	LITHOLOGY
	Triassic	Quaco Formation	Unit 17	Buff and reddish brown sandstone, maroon and green siltstone and mudstone and buff polymictic conglomerate
				FAULT CONTACT
PALEOZOIC	Early Pennsylvanian - Late Mississippian	Hopewell Group	Unit 16	Maroon and gray fanglomerate, siltstone, mudstone, and sandstone
				UNCONFORMITY WITH UNIT 14
	Mississippian	Windsor Group	Unit 15	Gypsum, maroon and green mudstone, and dark green sandstone
				FAULT CONTACT
	Carboniferous or Older	Unnamed Unit	Unit 14	Green epidotized basaltic breccia and dark red feldspathic wacke and siltstone, gray limestone; minor light green siltstone
				FAULT CONTACT
	Cambrian	Saint John Group	Unit 13	Grey, green, and maroon siltstone, sandstone, shale, quartzite, and quartzite-pebble conglomerate; minor maroon limestone and felsic volcanic rocks
				UNCONFORMITY AND/OR FAULT CONTACT
PRECAMBRIAN	Precambrian		Unit 12	Mainly felsic intrusive rocks; 12a, granodiorite, monzodiorite, gabbro, diabase, and rhyolite; 12b, granite; 12c, leucogranite (may be younger); 12d, low-K granite; 12e, keratophyre and rhyolite
			Unit 11	Diabase and gabbro
				INTRUSIVE CONTACT
	Late Hadrynian	Coldbrook Group	Unit 10	Fine- to medium-grained felsic and mafic tuffaceous rocks, grey and maroon siltstone and shale and minor grey limestone, maroon quartzose sandstone, and buff quartzite; buff and maroon arkosic sandstone
				FAULT CONTACT
			Unit 9	Medium and light green felsic tuffaceous rocks intercalated with dark green mafic tuffaceous rocks; minor pyritic siltstone (iron formation)
			Unit 8	Mainly dark green felsic tuffaceous rocks and agglomerate, dark green siliceous siltstone, grey limestone; minor mafic tuffaceous rocks
			Unit 7	Light grey and dark green polymictic and monomictic conglomerate, purple and green micaceous siltstone and sandstone, minor buff arkosic sandstone and green mafic tuffaceous rocks
			Unit 6	Dark green mafic tuffaceous rocks and flows, pillow lava, hyaloclastite, hyalotuff; minor felsic tuffaceous rocks, dark purple siltstone, chert, limestone, pyritic siltstone (iron formation), and granite-pebble conglomerate
			Unit 5	Dark green and orange felsic tuffaceous rocks and green and grey siltstone, shale, and quartzite; minor mafic tuffaceous rocks, green limestone, and steel grey and green siltstone and sandstone
			Unit 4	Green and gray mafic and felsic tuffaceous rocks, dark purple siltstone, and buff arkosic sandstone
				FAULT CONTACT
			Unit 3	Grayish green siltstone and sandstone; minor buff and reddish brown arkose
			Unit 2	Dark and olive green mafic tuffs and flows; minor felsic volcanic rocks
			Unit 1	Mainly red and buff lithic and vitric felsic volcanic rocks, rhyolitic flows and massive felsic domes; minor mafic volcanic rocks

Mafic flows that occur sporadically throughout Unit 2 are vesicular and massive, and are commonly highly epidotized. Primary features are generally destroyed by the regional tectonic deformation but at a few localities, chilled margins and highly vesiculated flow tops are present. Vesicles are filled with calcite, chlorite, quartz, epidote, or pyroxene. The groundmass exhibits a very fine grained, altered interstitial texture in which plagioclase laths are surrounded by chlorite.

Unit 3: This unit is composed of grey and greyish green siltstone and sandstone intercalated with rocks of Units 1 and 2.

The siltstone and sandstone sequences (Unit 3a) are generally not more than 20 m thick except on the upper part of the Quiddy River (Plate 83-34[R]) where the thickness exceeds 100 m. The unit consists predominantly of siltstone intercalated with fine- to coarse-grained sandstone. Beds are generally thin, but thicker beds (1 m and greater) of medium- to coarse-grained sandstone occur at some localities. Thin to medium parallel laminations are ubiquitous in the siltstone beds. Graded bedding occurs in a few of the thicker sandstone beds. Along the road to Christie Lake near Broad Brook, Plate 83-34(R), there are beds less than 1 m thick; they show overall grading and exhibit typical Bouma a-e intervals (Bouma 1962) characteristic of turbidites (Figure 4).

The sandstones of Unit 3a are feldspathic or lithic wackes and less commonly quartz wackes and arkosic sandstones. The lithic wackes contain variable amounts of altered volcanogenic material including relict pyroxene and fragments of mafic and felsic volcanic rocks. The fine-grained sandstone and siltstone contain quartz and minor amounts of broken feldspar. The matrix of all these lithotypes is composed of chlorite and recrystallized quartz. Arkose (Unit 3b) outcrops only in the upper part of Little Salmon River, Plate 83-34(R).

Units 1, 2, and 3 are intercalated and commonly exhibit gradational contact relationships. Although definite stratigraphic sequences, containing alternations of the lithotypes mentioned above, can be deduced in a given area, the sequences cannot be correlated across major faults.

Unit 4: This unit is well exposed in three localities: near the mouth of Quiddy River (Plates 83-34[R], 83-35B[R], and 83-36[R]), along East Goose Creek, and on Pine Brook (both on Plate 83-36[R]). It consists of dark green, highly sheared mafic tuffaceous rocks and lesser amounts of felsic tuffaceous rocks, dark purple siltstone, and buff arkosic sandstone.

Arkosic sandstone (Unit 4a) occurs along Pine Brook. The arkose is fairly homogeneous, medium-grained sandstone composed of well-sorted and rounded quartz and feldspar fragments in a recrystallized quartzose matrix. Outcrops of Unit 4a, north of Pine Brook (along the road), contain randomly distributed, rounded, pebble- and cobble-sized fragments of red and buff felsic volcanic rocks that comprise 20-30% of the total rock.

The rocks of Unit 4, that lie stratigraphically beneath Unit 4a, are not well exposed in the project area but a few outcrops of highly sheared mafic and felsic tuffaceous rocks occur on the upper part of Goose River. One rusty-weathering, pyritic zone in felsic tuff is particularly interesting because it contains abundant bornite.

The mafic tuffaceous rocks of Unit 4b, overlying Unit 4a, are generally fine- to medium-grained and few of their primary features are preserved. In some localities, they occur in thin beds that exhibit thin to medium parallel laminations. Minor amounts of relatively featureless, purple and grey siltstone are intercalated with the mafic tuffs at this locality.

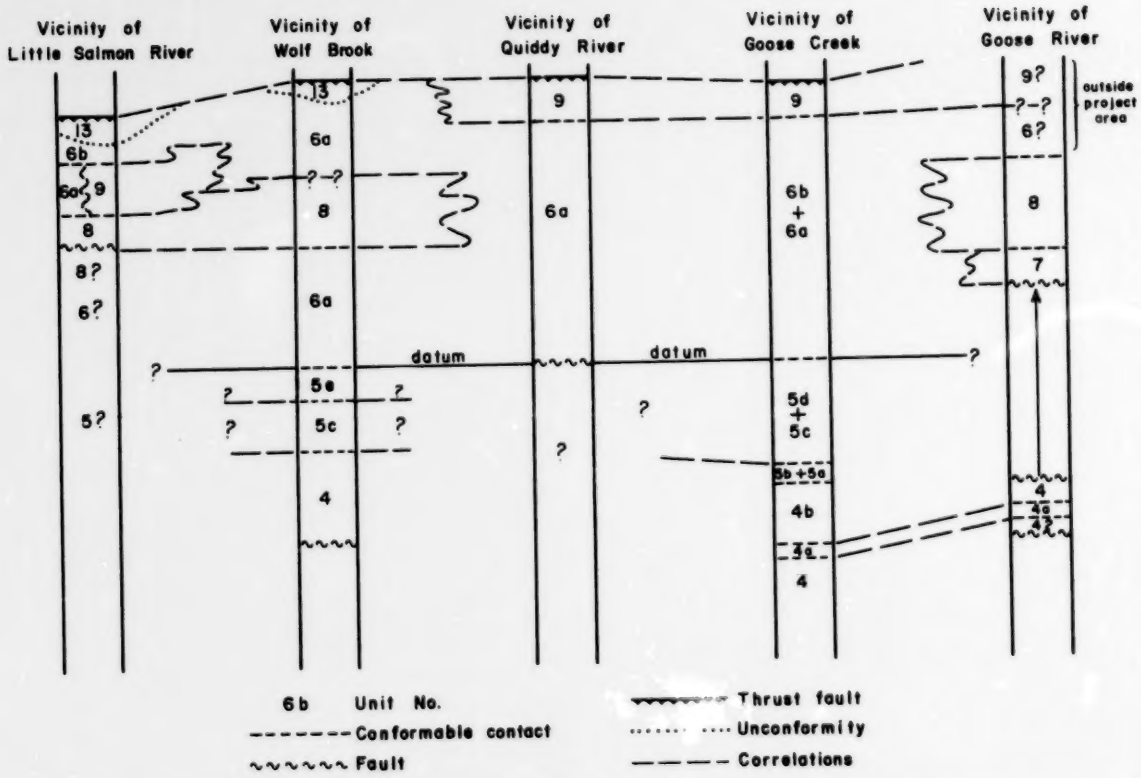


FIGURE 3. Schematic stratigraphic columns and correlations for Domains B and C.

FIGURE 4. Turbidites in Unit 3a near Broad Brook. Hammer head is 10 cm long.

Dark purple siltstone (Unit 4c), which exhibits thin to medium parallel laminations, is particularly abundant in thin to thick beds on Pine Brook. The laminations consist of laminae rich in fine-grained quartz and volcanogenic debris that alternate with very fine grained laminae containing submicroscopic constituents.

Unit 5: This unit consists of a variety of rock types, but dark green felsic tuffaceous rocks predominate. The unit occurs in the Goose Creek (Plate 83-36[R]) and Telegraph Brook (Plates 83-34[R], 83-35B[R]) areas.

The lowermost part of Unit 5 is composed of siltstone, shale, quartzite (Unit 5a), and minor limestone (Unit 5b). Unit 5a crops out on Flat Running Brook, Pine Brook, and along the entire length of East Goose Creek (Plate 83-36[R]). Dark grey and commonly highly pyritic siltstone is the predominant lithology of Unit 5a. The siltstone is highly sheared and is intercalated with thick and very thick beds of grey and white quartzite. The quartzite is massive and composed of medium-grained quartz and minor amounts of feldspar in a recrystallized quartzose matrix. Minor amounts of limestone (Unit 5b) are intercalated with Unit 5a at the junction of East Goose Creek and Pine Brook, and on Flat Running Brook. At the former locality, two light brown, thinly laminated beds about 5 cm thick are interbedded with the siltstone. On Flat Running Brook, the limestone occurs in one thick bed, is dark grey and has a knobby appearance. Lateral equivalents of these beds have not been found elsewhere in the project area.

Unit 5c occurs along Goose Creek (Plate 83-36[R]) and on the lower part of Telegraph Brook (Plates 83-34[R], 83-35B[R]). On Goose Creek, it consists of intensely sheared, medium-grained, green and orange felsic tuffaceous rocks, and subordinate amounts of black mafic tuffaceous rocks that are similar to those described in the previous section. On Telegraph Brook, Unit 5c is composed almost entirely of dark green felsic tuffaceous rocks. Unit 5d occurs in minor amounts on Goose Creek just north of its junction with East Goose Creek. The dark grey siltstone of this unit is similar to that in Unit 5a.

The lithotypes comprising Units 5c and 5d occur in medium to thick laterally continuous beds but most primary sedimentary structures are obscured by the regional tectonic fabric. The green felsic tuffaceous rocks are composed of about equal amounts of quartz and plagioclase (50% of the total rock) set in a very fine grained quartz-chlorite matrix. The mineralogy of the orange felsic tuffaceous rocks is similar to the green felsic tuffaceous rocks except pyrite is much more abundant forming up to 10% of the rock.

Unit 5e is composed of steel grey and green siltstone and sandstone, mafic tuffaceous rocks, and minor amounts of pebbly sandstone. This unit has a limited areal extent occurring only in the Telegraph Brook area.

Fine- and medium-grained mafic lithic tuffaceous rocks comprise the lowermost part of Unit 5e (Figure 5). They occur in thin, even beds composed of altered plagioclase fragments in a chloritic matrix. Each bed has light laminae that are enriched, and dark laminae that are depleted, in feldspar fragments. These tuffaceous rocks are overlain by, and intercalated with, purple siltstone that is also thinly bedded and exhibits thin and medium laminae. The laminae are defined by very fine grained silt alternating with sand containing abundant mafic tuff fragments or quartz and feldspar fragments. The purple siltstone also commonly contains minor amounts (10%) of well-rounded felsic and mafic tuffaceous pebbles in the section on Telegraph Brook. Grey and green siltstone and sandstone overlie the purple siltstone on Hunter Brook (Plate 83-35B[R]) and along the coast nearby, but are terterminated along strike to the north by the Wolf Brook Fault. These rocks are strongly deformed and are almost totally altered to muscovite, sericite, and chlorite. A few relict quartz grains are preserved in sandy beds.

FIGURE 5. Mafic, lithic tuffaceous rocks and purple siltstones at the mouth of Telegraph Brook (Unit 5e). Hammer handle is 20 cm long.

The contact of Unit 5 with Unit 4 is exposed at several localities on East Goose Creek and is sharp and conformable. Units 5a through 5e are also conformable.

Unit 6: This unit constitutes an extensive mafic volcanic sequence that crops out across the project area from the mouth of Cradle Brook northeastward to Point Wolfe River near Tabor Brook tributary (Plates 83-35A[R], 83-35B[R], and 83-36[R]). It is composed of mafic tuffaceous rocks, mafic flows (in places pillowed), hyaloclastites, hyalotuffs, and minor felsic volcanic rocks, limestone, siltstone, and chert. The best exposures of the mafic tuffaceous rocks (Unit 6a) occur on the Quiddy River (Plates 83-34[R], 83-36[R]) and on Wolf Brook (Plate 83-35B[R]), about 3 kms and 1 km from the coast, respectively. Unit 6b occurs in coastal sections from the Cradle Brook area to Telegraph Brook (Plate 83-35A[R], 83-35B[R]) and along the roads near the headwaters of Goose Creek (Plate 83-36[R]).

The mafic tuffaceous rocks (Unit 6a) are dark green and are generally highly deformed. The rocks are fine-grained to very coarse grained on Quiddy River but mainly fine-grained on Wolf Brook. The fine-grained tuff contains variable amounts of altered plagioclase and mafic fragments and a very fine grained matrix of recrystallized plagioclase and chlorite. The coarse-grained mafic tuffaceous rocks contain similar fine-grained components and variable amounts (up to 60%) of coarser mafic and felsic volcanic fragments. Epidote alteration is ubiquitous throughout the unit. The fine-grained mafic tuffaceous rocks on Wolf Brook commonly occur in medium beds that exhibit colour banding similar to that in Unit 5e.

The mafic flows, hyaloclastite, hyalotuff, and minor siltstone, limestone, and chert are designated as Unit 6b. The pillowed flows are generally highly vesiculated, occur in very thick beds, at least 5 m thick, and are intercalated with hyaloclastites and hyalotuffs (Figure 6). The hyaloclastites occur in crudely graded beds several metres thick in which the size of pillow fragments gradually decrease toward the tops of beds. Lenses of hyalotuff, generally 1 to 2 m thick, overlie the hyaloclastites at some localities.

The mafic flows are fairly massive whereas the hyaloclastics and hyalotuffs have a well-developed tectonic fabric. Primary pilotaxitic texture, consisting of very fine grained altered plagioclase laths embedded in a chloritic groundmass, is well preserved in the flows. Vesicles are filled with quartz, calcite, epidote, or chlorite. Calcite and epidote alteration occurs throughout the pillow lavas. Primary textures in the hyaloclastites and hyalotuffs are almost completely obliterated by deformation.

Blocks of thinly bedded white chert, generally less than 1 m in diameter, occur in the hyaloclastites east of Cradle Brook. The chert is parallel and cross laminated. The discontinuous nature of the blocks, and differences in bedding attitudes in the blocks relative to the surrounding mafic volcanic rocks, indicates dislodgement of the chert from its original position.

Thin discontinuous lenses, up to 15 cm in length, and thin continuous beds of brownish grey limestone and dark green siliceous siltstone occur in the hyaloclastites east of Cradle Brook. The lenses of sediment occur within distinct layers in the mafic volcanic sequence and were undoubtedly deposited during volcanism.

Near the mouth of Wolf Brook, minor amounts of dark purple siltstone (Unit 6c), green pyritic siltstone (iron formation), (Unit 6d), and granite-pebble conglomerate (Unit 6e) occur. The purple siltstone is identical to that described in Unit 5e. One bed, about 2 m thick, of green pyritic siltstone exhibits fine to medium laminations that consist of alternating

FIGURE 6. Pillow lava and pillow breccia near the mouth of Cradle Brook (Unit 6b).

pyrite-rich and pyrite-depleted laminae. Some laminations contain nearly 100% pyrite. In one small outcrop of poorly sorted conglomerate, most of the pebbles and cobbles are massive granite and comprise about 60% of the total rock. The matrix is medium-grained arkosic sandstone.

The contact of Unit 6 with Unit 5 is either faulted or obscured by intrusive rocks, but bedding attitudes indicate that the two are conformable (Figure 3, Column 2). The distribution of Units 6a and 6b indicates that they are laterally equivalent facies.

Unit 7: This unit occurs on the Bay of Fundy coast east of Rose Brook (Plate 83-36[R]) and is composed of a variety of detrital sedimentary rocks including conglomerate, siltstone, sandstone, and minor mafic tuffaceous rocks. The entire unit may represent a crude fining-upward sequence in which conglomerate predominates at the base and siltstone predominates at the top.

The conglomerate is highly deformed and occurs in thick to very thick, poorly sorted massive beds. The pebbles and cobbles are well rounded and generally constitute less than 50% of the total rock. The rounding of these constituents could be either a tectonic or a primary sedimentary feature.

The conglomerate varies in colour from light grey to dark purple and green. At the base of the unit, the conglomerate is monomictic and contains pebbles and cobbles composed of light grey, massive quartzite or granite. Other beds are polymictic and contain, in addition to quartzite and granite, pebbles and cobbles of felsic volcanic rocks and maroon sandstone.

Buff arkosic sandstone and mafic tuffaceous rocks become more prevalent and conglomerate decreases in abundance toward the middle of Unit 7. These lithotypes occur in thick to very thick beds, in which primary sedimentary features are not preserved. The arkosic sandstone and mafic tuffaceous rocks are similar in texture and composition to those described in Units 4a and 4b. Purple and dark green micaceous siltstone and sandstone predominate in the upper part of Unit 7. These are also observed in thick to very thick beds in which no other primary sedimentary features are preserved.

The base of Unit 7 appears to be faulted near the mouth of Goose River (Plate 83-36[R]) but it is apparently conformably overlain by Unit 8. This relationship indicates that Unit 7, like Unit 8, is laterally equivalent to Unit 6 (see description of Unit 8).

Unit 8: Unit 8 contains a variety of felsic volcanic rocks. The unit crops out at several localities along the Bay of Fundy coast between Little Salmon River and Hunter Brook (Plate 83-35B[R]) and at the mouth of Goose River (Plate 83-36[R]).

The most diagnostic lithotype in this unit is a medium-grained, dark green felsic agglomerate (Unit 8a) that commonly contains large rounded bombs of pink vitrophyre. The felsic agglomerate occurs sporadically in thick to very thick beds throughout Unit 8, and is particularly well exposed near Wolf Brook. The vitrophyric bombs, ranging in diameter from 3 to 30 cm, are commonly graded within beds and constitute up to 60 per cent of the total rock. Similar rocks, that occur along the shore west of Wolf Brook, contain large, rounded limestone fragments instead of vitrophyre. These fragments are probably remnants of the sedimentary pile through which the magma passed. The matrix is composed of quartz, chlorite, and minor amounts of lithic debris. Medium- to coarse-grained felsic volcanic rocks compositionally similar to this matrix are also abundant in Unit 8.

Some other types of felsic tuffaceous rocks that occur in Unit 8 include green and grey, medium-grained feldspar- and quartz-crystal tuff, and pink to grey, very fine grained felsic tuffaceous rocks.

Dark green siliceous siltstone (Unit 8b) is exposed in thick sequences (5-10 m) throughout Unit 8. Bedding is generally thin to medium and the rocks commonly exhibit fine, parallel colour laminations. The siltstone consists of quartz and minor amounts of volcanic debris in either a very fine grained quartz-chlorite or a carbonate matrix. The siltstone is commonly highly pyritic (up to 20%), and contains minor amounts of disseminated bornite and chalcopyrite.

Dark grey limestone (Unit 8c), that weathers chalky white, is also abundant in Unit 8. The limestone occurs in thick beds and commonly exhibits medium to thick parallel or cross laminations. The limestone is completely recrystallized and contains no clastic debris. Samples were analysed for conodonts but none were found (G. Nowlan, written communication, 1981).

Rusty-weathering pyritic zones, up to 10 m wide, that contain up to 80% disseminated pyrite and minor amounts of chalcopyrite, are a characteristic feature of Unit 8. These are laterally persistent zones and appear to comprise either altered, pyrite-rich siliceous siltstone or felsic tuffaceous rocks.

Unit 8 occurs on both sides of the Wolf Brook Fault, near the mouth of Wolf Brook. South of this fault, it appears to be conformably underlain by mafic volcanic rocks of Unit 6, whereas north of the fault it is overlain by mafic volcanic rocks of Unit 6 (Figure 3, Column 2). Therefore, Unit 8 appears to be laterally equivalent to Unit 6. South of the Wolf Brook Fault near the mouth of Goose River, Unit 8 is conformably underlain by rocks of Unit 7 (Figure 3, Column 5) and is overlain by mafic volcanics (outside the project area) that may be equivalent to Unit 6.

Unit 9: This unit consists of intercalated felsic and mafic tuffaceous rocks and minor pyritic siltstone (iron formation). It occurs on the headwaters of Goose Creek (Plate 83-36[R]), on the Quiddy River south of Walton Brook (Plate 83-34[R]), and on the shore west of Little Salmon River (Plate 83-35B[R]).

The felsic and mafic tuffaceous rocks are fine-grained to very coarse grained on the Quiddy River but are generally fine- to medium-grained in the Goose Creek and Little Salmon River areas. Very thick beds of felsic and mafic tuffaceous rocks are the only preserved primary sedimentary structures.

The felsic tuffaceous rocks vary in colour from medium green to light green and white. They consist of fragments of altered feldspar, quartz, and felsic volcanic rocks with a very fine grained, recrystallized quartzose matrix. Many of the pale-coloured felsic tuffaceous rocks contain abundant (up to 30%) disseminated pyrite and minor amounts of chalcopyrite and bornite. These rocks produce rusty-weathered zones particularly where shearing is intense.

The mafic tuffaceous rocks are similar to those described in Unit 6a. Also minor amounts of pyritic siltstone (Unit 9a), similar to Unit 6d, occur on the Quiddy River. These siltstones contain minor amounts of bornite and chalcopyrite.

Unit 9 conformably overlies Unit 6 on the Quiddy River and on Goose Creek but appears to underlie Unit 6 near the mouth of Little Salmon River (Figure 3, Column 1). Therefore, Unit 9 in part overlies, but is also a facies equivalent of, Unit 6.

Unit 10: Rocks designated as Unit 10 are of unknown stratigraphic position and occur in fault blocks on the Point Wolfe River in the northeastern part of the project area, and southeast of the Wolf Brook Fault in the Rose Brook area, both on Plate 83-36(P). They consist of a wide variety of lithotypes including fine- to medium-grained felsic and mafic tuffaceous rocks, grey and maroon siltstone and shale, minor amounts of limestone, maroon quartzose sandstone, and buff quartzite. Many of these rock types are similar to rocks in other units described in preceding pages and are therefore not described in detail.

Unit 10a occurs on Goose River and is similar to Unit 4a in that it consists of arkosic sandstone and contains an assortment of rounded and poorly sorted pebble-sized fragments including quartzite, felsic tuffaceous rocks, and maroon siltstone and sandstone.

Unit 10b occurs on Point Wolfe River and is similar to Unit 13b in that it consists of intercalated maroon and grey siltstone and shale, but it also contains minor grey limestone. The siltstone occurs in finely laminated thick beds lacking sedimentary structures. The limestone is massive and occurs in beds less than 1 m thick. It was sampled for conodonts but none were found (G. Nowlan, written communication, 1981).

Unit 10c also occurs on Point Wolfe River. It consists of a thick succession of interbedded maroon arkosic sandstone and mafic tuffaceous rocks. The arkosic sandstone contains variable amounts of mafic tuffaceous debris.

Interpretation of Precambrian Stratigraphy:

Units 1 to 10 are considered to be Precambrian (Late Hadrynian) in age and stratigraphic equivalents of the Coldbrook Group (Alcock 1938, Ruitenberg et al. 1975) near Saint John.

The rocks northwest of the Cradle Brook-Walton Brook Fault (Units 1 to 3) appear to have been deposited in a subaerial to shallow subaqueous environment, perhaps in a gradually subsiding basin, because of the presence of oxidized felsic volcanic rocks intercalated with grey, green, and red sedimentary rocks. Periods of intense felsic and mafic volcanic activity produced voluminous, unsorted tuffaceous deposits, highly vesiculated mafic flows, and extensive felsic flows. The felsic volcanic rocks are mostly oxidized (pink and red colours) and there is little evidence of reworking of the volcanic debris. Intercalated with these rocks are finely laminated siltstone and commonly, graded sandstone. These sediments contain variable amounts of volcanic debris undoubtedly derived from the volcanic pile.

The Precambrian rocks southeast of the Cradle Brook-Walton Brook Fault (Units 4 to 10) within the project area, however, appear to have been deposited almost entirely in a subaqueous environment. Periods of intense volcanic activity in this area also produced voluminous tuffaceous deposits but these deposits are generally finer grained than those northwest of the fault and are commonly reworked producing well-sorted and laminated deposits. The volcanic flows are all mafic in composition and commonly occur as highly vesiculated pillow lavas and hyaloclastites. During intermittent periods of quiescence, limestone, chert, quartzite, dark purple and grey siltstone, sandstone, and shale were deposited throughout the section.

CAMBRIAN ROCKS

Saint John Group (Unit 13):

Unit 13 is composed of grey and maroon siltstone, sandstone, shale, quartzite, quartzite-pebble conglomerate, and minor amounts of felsic volcanic rocks and limestone. It is exposed in coastal sections east and west of Cradle Brook and on tributaries of Wolf Brook, in the area between Cradle Brook-Walton Brook Fault and Wolf Brook Fault; and on Seely Beach Brook and Big Salmon River, all on Plates 83-35A(R), 83-35B(R).

A distinctive maroon conglomerate, containing abundant well-rounded but poorly sorted pebbles and cobbles in a sandy quartzose matrix, occurs at the base of Unit 13a. The thickness of this conglomerate varies from 1 m to over 10 m. It is repeated by faulting in the Big Salmon River area. Clasts in the conglomerate are composed predominantly of maroon quartzite and white or milky quartz with a few clasts of volcanic and sedimentary rocks. Most of the clasts do not exhibit an obvious pre-depositional fabric except for a few of the volcanic clasts that resemble volcanic rocks of the area northwest of the Cradle Brook-Walton Brook Fault.

The conglomerate is generally overlain by medium-bedded and medium-grained maroon quartzite of Unit 13a that varies in thickness from 1 m to over 5 m. In the Big Salmon River area, however, the quartzite is white and is much thicker. The quartzite is massive or parallel laminated and commonly exhibits large-scale cross-bedding. Minor amounts of very fine grained red felsic volcanic rocks and grey shale are intercalated with the quartzites on Big Salmon River. These volcanic rocks exhibit flow banding that is concordant with bedding surfaces.

Unit 13b comprises an unknown thickness of sheared, green, grey, and maroon siltstone, sandstone, shale, and minor amounts of limestone overlying the quartzite of Unit 13a. The siltstone, sandstone, and shale are intercalated and generally occur in sequences several metres thick. They are thinly bedded and exhibit thin to medium parallel laminations. Several ovoid masses of greyish green limestone (about 10 cm in diameter) that resemble concretions, occur within siltstone near Cradle Brook.

Rocks of questionable age, occurring along Goose Creek, Rose Brook, Brandy Brook, and Long Beach Brook are also designated as Unit 13. Those that outcrop in a fault block on Goose River and Rose Brook (Plate 83-36[R]) contain the distinctive maroon quartzite-pebble conglomerate in addition to maroon feldspathic quartzite and micaceous grey and maroon siltstone, sandstone, and shale. Intercalated grey and maroon micaceous siltstone and sandstone, grey massive quartzite, and minor buff arkosic sandstone that occur on Brandy Brook and along strike near the mouth of Quiddy River (Plate 83-36[R]), are considered equivalents of Unit 13, since boulders of quartzite-pebble conglomerate have been found in the vicinity. The exposed portion of the Brandy Brook section is similar to Unit 13b of the Wolf Brook area but contains a distinctive pebbly arkosic sandstone.

The basal conglomerate in Unit 13 unconformably overlies Unit 6b in the Cradle Brook area. The basal contact in the Wolf Brook area is sheared and the upper contact, although not exposed, is probably also faulted.

Interpretation of Cambrian Stratigraphy:

Unit 13 either unconformably overlies or is in fault contact with Precambrian strata. It is probably equivalent in part to Lowermost Cambrian strata in the Saint John area (Ratcliffe Brook Formation of the Saint John Group; Hayes and Howell 1937). The limestone in this unit was analysed for conodonts but none were found (G. Nowlan, written communication, 1981). Details of the correlation are given by McLeod and McCutcheon (1981). Ruitenberg et al. (1979) assigned these rocks to their Unit 4a and 4b of the Coldbrook Group and Kindle (1962) assigned these to his Unit 2 of the Coldbrook Group.

Rocks of Unit 13 reflect a drastic change in the depositional and tectonic environment from the preceding Precambrian units. Similar initial Cambrian deposits (quartzite and quartzite-pebble conglomerate, Unit 13a) are interpreted to represent a marginal basinal facies associated with the formation of the Iapetus Ocean and the shale, sandstone, and limestone (Unit 13b) overlying the initial deposits reflect the transgression of that ocean over the Precambrian Avalonian platform (Rast et al. 1976; Ruitenberg et al. 1977).

CARBONIFEROUS OR OLDER ROCKS

Unnamed Unit (Unit 14):

Unit 14 occurs in the area southeast of the Wolf Brook Fault as elongate, discontinuous fault slivers between Martin Head and Rose Brook, Plate 83-36(R). Mafic volcanic breccia, limestone, and subordinate amounts of sandstone and siltstone are the principle components of Unit 14.

The mafic volcanic breccias (Unit 14a) occur in thick sequences (greater than 10 m) in which primary features are nearly totally obliterated by deformation and epidotization. Intercalated with these breccias are thinly bedded and commonly crudely graded beds of dark red, and locally green, feldspathic wacke and siltstone. These beds are laterally continuous and vary from a few metres to several metres in width.

About 15 m of dark grey limestone (Unit 14b) conformably overlies Unit 14a at the mouth of Goose Creek. The limestone occurs in thin to medium parallel-laminated beds that are composed entirely of recrystallized calcite. Some beds near the top of this unit contain some clastic debris, exhibit assymetrical ripple marks, and possibly contain trace fossils.

Unit 14 is unconformably or disconformably overlain by Unit 16; the lower contact of the unit is not exposed. Limestone samples were analysed for microfossils, but none were found (G. Nowlan, written communication, 1981). The limestone may be correlative with the middle Viséan Macumber Formation, part of the Windsor Group in southern New Brunswick described by McCutcheon (1981), but it could be older.

CARBONIFEROUS ROCKS

Windsor Group (Unit 15):

This unit consists of gypsum, anhydrite, and green sandstone near Martin Head, Plate 83-35B(R). It is considered to be Carboniferous in age and has been correlated with the Windsor Group by several workers, including Kindle (1962). The limestone deposits in this sequence record a widespread marine transgression (McLeod 1979a).

Hopewell Group (Unit 16):

This unit consists of red conglomerate, red or grey shale, and mudstone-sandstone on the shore near Goose Creek, Plate 83-36(R). The section at Martin Head is described in detail by Kindle (1962) and will not be reiterated here. The conglomerate is polymictic and contains poorly sorted, angular, and commonly deformed cobbles and pebbles that were undoubtedly derived from the units described in the preceding sections. Shale and mudstone overlie the conglomerate in thick units that have been intensely sheared and crumpled by faulting.

The northern contact of Unit 16 is faulted against rocks of Unit 10, but the lower contact is an unconformity with Unit 14b. This unconformity dips vertically and occurs as a thick (3 m wide) regolith-like zone developed between the conglomerate and the limestone of Unit 14b. This zone contains numerous broken and contorted angular blocks of limestone up to 1 m in width. The interstices between blocks are filled with calcite and quartz. Unit 16 has been mapped as being equivalent to the Hopewell Group by Ruitenberg et al. (1975) and that correlation is accepted in this report.

Similar Carboniferous conglomerates exposed elsewhere in southern New Brunswick are considered to be molasse deposits that formed after the Devonian Acadian Orogeny.

TRIASSIC ROCKS

Quaco Formation (Unit 17):

This unit consists of buff and reddish brown sandstone, maroon and green siltstone and mudstone, and buff polymictic conglomerate. These rocks occur in a small fault block at Martin Head (Plate 83-35B[R]) and in another fault block at Tufts Point (Plate 83-35A[R]). Hayes and Howell (1937) recognized that they were Triassic in age and correlated them with the Quaco Formation near St. Martins.

PLUTONIC ROCKS

The stratified rocks in the project area have been intruded by granitoid rocks, gabbro, diabase and fine-grained felsic rocks. For descriptive purposes, these intrusive rocks are divided into mafic (Unit 11) and felsic (Unit 12) intrusions.

Mafic Intrusions (Unit 11):

Mafic intrusions occur throughout the project area and exhibit minor variations in their texture and mode of occurrence. The main rock types are diabase, gabbro, and porphyritic diabase and gabbro.

Deformed and undeformed diabase dykes are the most common type of mafic intrusion northwest of the Cradle Brook-Walton Brook Fault. They generally occur throughout the zone as isolated dykes 1 to 5 m wide and are particularly abundant in many of the mafic volcanic units. They commonly strike parallel to the local tectonic fabric. The dykes are typical diabases in that they exhibit subophitic and intergranular textures and are composed of clinopyroxene and plagioclase crystals, opaque oxides and a chloritic matrix. Minor amounts of porphyritic diabase, that contain plagioclase phenocrysts up to 2 cm in length, also occur northwest of the fault.

Gabbroic intrusions are not common in the area northwest of the Cradle Brook-Walton Brook Fault but are present within the Bonnell Brook Pluton (Unit 12a). A poorly defined gabbroic plug occurs near the headwaters of Dustan Brook. The gabbro is similar in composition to the diabase but exhibits ophitic to subophitic textures.

Massive and deformed gabbro plugs and diabase dykes and sills are abundant in the Precambrian units southeast of the Cradle Brook-Walton Brook Fault, and are similar in texture and composition to those northwest of the fault. Those southeast of the Wolf Brook Fault are too small to be delineated on the maps. Gabbroic rocks are particularly numerous on Rapidy Brook (Plate 83-35B[R]) and on the upper part of Goose Creek (Plate 83-36[ ]), but delineation of distinct plugs is difficult. Gabbroic intrusions, a few tens of metres wide, crop out as resistant headlands in shore sections. Minor amounts of porphyritic gabbro, that contain altered plagioclase phenocrysts up to 3 cm long, also occur southeast of the Cradle Brook-Walton Brook Fault. A few undeformed diabase dykes occur throughout the same area and even intrude the Cambrian rocks on Big Salmon River, Plate 83-35A(R).

One gabbroic plug that occurs on the Quiddy River, about 3 km from its mouth (Plate 83-35B[R]), exhibits primary igneous layering. The layers, which are 10-15 cm thick, contain abnormally high proportions of coarse-grained plagioclase crystals.

Felsic Intrusions (Unit 12):

The intrusive rocks that occur in the northwestern part of the project area (Unit 12a) are part of the Bonnell Brook Pluton (Unit 8 of Central Intrusive Belt of Ruitenberg et al. 1979). The southern part of this pluton is exposed along the upper part of the Big Salmon River.

Ruitenberg et al. (1979) provide detailed descriptions of this pluton (including modal analyses and QAP diagrams) which will not be reiterated in this report. The pluton contains approximately equal proportions of medium-grained granodiorite and monzodiorite that exhibit hypidiomorphic to allotriomorphic granular textures. Significant amounts of fine-grained felsic (rhyolite?) and mafic rocks also occur in these plutons. The margin of the pluton is deformed by the regional cataclastic deformation but the interior is relatively massive and only slightly metamorphosed.

Contacts between the felsic and mafic rock types in the Bonnell Brook Pluton are complex, and relationships were not mapped in detail. Contact aureoles of the plutons have been obscured by later deformation and metamorphism.

Minor amounts of granodiorite, intrusive rhyolite, diabase, and gabbro occur elsewhere northwest of the Cradle Brook-Walton Brook Fault. One small stock of medium-grained granodiorite occurs on the upper part of Little Salmon River. It is massive and is identical to the granodiorite in the Bonnell Brook Pluton.

Dark grey, very fine grained felsic stocks outcrop on isolated resistant hills near the margin of the Point Wolfe River Pluton in the upper Little Salmon River area, Plate 83-34(R). These are undoubtedly closely associated with the large intrusive bodies to the north and west.

The felsic intrusions that occur southeast of the Cradle Brook-Walton Brook Fault consist predominantly of granite, keratophyre porphyry, leucogranite, and minor K-poor granite. These intrusions vary in width from a few metres to several kilometres and generally are oriented parallel to the regional structural trend. The margins, as well as parts of the interiors of these intrusions, are deformed by the regional tectonic fabric.

A large medium-grained granite (Unit 12b) crops out along the main roads and on stream sections in the Goose Creek - Goose River area, Plate 83-36(R). The pluton had been previously mapped and referred to as the Goose Creek Sill, by Ruitenberg et al. (1979) who provided detailed descriptions. The northern part of the pluton has recently been mapped by Barr (1987).

Smaller plugs, similar in composition, occur on Rapidy Brook (Plate 83-35B[R]), and Quiddy River and Shear Brook (both on Plate 83-36[R]). Diabase dykes intrude these granites but are volumetrically insignificant. The contacts of these plutons, when mapped in detail, cross-cut the regional tectonic fabric and bedding, and therefore cannot be considered sills as suggested by Ruitenberg et al. (1979).

Several small plugs of medium- and coarse-grained leucogranite (Unit 12c) occur on Wolf Brook, Telegraph Brook, and Goose River (Plates 83-34[R], 83-35B[R], and 83-36[R] respectively). They typically exhibit allotriomorphic granular textures, contain few or no mafic minerals, and are commonly highly fractured. All of the minerals in these rocks are characteristically strained and broken and contain abundant muscovite-filled cracks and fractures.

The distribution of these leucogranites along the Wolf Brook Fault, in addition to their fractured appearance, indicates emplacement along these zones of structural weakness. Furthermore, the intrusions on Wolf and Telegraph brooks may also be part of the intrusion on Goose River if allowance is made for strike-slip movement along the Wolf Brook Fault.

Minor low-K granite (Unit 12d) occurs southeast of the Cradle Brook-Walton Brook Fault. Two small intrusions were mapped on Shear Brook, Plate 83-36(R). These intrusions are virtually indistinguishable in the field from the granites of Unit 12b.

The keratophyre porphyry (Unit 12e) is most abundant in the Telegraph Brook area (Plate 83-34[R]), where it forms fairly large homogeneous intrusive masses about 1 km wide, but is also abundant as smaller intrusions, dykes, and sills in other areas southeast of the Cradle Brook-Walton Brook Fault. The larger intrusions are pink, porphyritic, and contain variable proportions of quartz and altered plagioclase phenocrysts from 2 to 5 mm in length set in a very fine grained crystalline matrix of quartz and chlorite. Most of the smaller intrusions are pink or grey, very fine grained, and massive.

Timing of Intrusive Events:

The relative timing of intrusive events is not clear in the project area. Factors contributing to this include: the lack of reliable absolute age dates, the complexity of intrusive relationships in a given area or pluton, and the random nature with which the regional cataclastic deformation affects some of the intrusive rocks.

Evidence for at least three periods of diabase dyke emplacement is present in the project area. Two periods of emplacement occurred before development of the regional tectonic fabric and one period of emplacement occurred after this event. In the Goose Creek area (Plate 83-36[R]), plutons of Unit 12b intrude and are intruded by diabase, all of which exhibit some effects of deformation. In the Cradle Brook area (Plates 83-35A[R], 83-35B[R]), however, several massive diabase dykes cross-cut the regional tectonic fabric.

The emplacement of the keratophyre porphyries (Unit 12e) may be temporally related to emplacement of the granitoid rocks (Unit 12a and 12b). The porphyries cross-cut mafic intrusive rocks but are also intruded by later diabase dykes.

The age of the intrusive rocks is not well established. The "Ordovician and Older?" age suggested by Ruitenberg et al. (1975) for the large granodiorite and monzodiorite intrusions in the Caledonian Highlands (including the Point Wolfe River Pluton and the Bonnell Brook Pluton) is based on K-Ar dates given in Ruitenberg et al. (1979) and in Leech et al. (1963). One Rb-Sr whole rock date of 530 $\pm$ 16 Ma. for the Bonnell Brook Pluton indicates a Cambrian age. (C. Brooks, written communication, 1980). However, conglomerates that are demonstrably part of the Cambrian succession contain clasts of granitoid

rocks similar to those in Units 12a and 12b, indicating that some of them are Precambrian. Some of the leucogranites (Unit 12c) may be post-Cambrian in age since on Goose River, large inclusions of rocks that resemble those in the Cambrian succession are incorporated in the leucogranite. However, on the tributaries of Wolf Brook, Cambrian rocks (Unit 13) appear to overlie the leucogranite, or at least, are not intruded by it.

It is postulated that the majority of intrusive rocks in the project area were injected prior to deposition of the Cambrian rocks and that absolute age dates are anomalously young. Cormier (1963) suggested that dates he obtained for volcanic rocks in the Coldbrook Group, as well as for other Precambrian volcanic rocks in the Northern Appalachians, were reset during subsequent orogenies due to the mobility of Rb and Sr.

In summary, there appear to be several periods of mafic intrusive activity but only one period of major felsic intrusive activity. The bulk of the intrusions are considered to be Late Precambrian in age with the possible exceptions of the mafic dykes that cross-cut the regional tectonic fabric and the leucogranites.

STRUCTURAL GEOLOGY

The project area lies within a structurally complex belt that is characterized by pervasive cataclastic deformation, several episodes of folding, and numerous faulting events. It is part of the Fundy Cataclastic Zone, Subzone 3 of Ruitenberg et al. (1979). The area is divided into three major northeast-striking fault blocks referred to as Domains A, B, and C (Figure 1b). Domain A constitutes the distinct package of rocks that occurs north of the Cradle Brook - Walton Brook Fault and that differs from rocks in Domains B and C in both lithology and structure. These domains have been affected by the pervasive cataclastic deformation but cleavage attitudes vary considerably from domain to domain. Some fault blocks contain unique styles of folding not present in other blocks. The metamorphic grade is almost always lower greenschist facies. Biotite is developed as a metamorphic mineral at some localities.

The southeastern boundary of Domain A is marked by a major southward-directed thrust fault, the Cradle Brook-Walton Brook Fault (Figure 1b), and by other faults to the west of Cradle Brook.

Domains B and C, respectively, occur to the northwest and southeast of the Wolf Brook Fault. Domain C is a complex wrench fault zone in which fault blocks are composed of numerous rock types of various ages. Some of these rock types are unique to Domain C but most are similar to those in Domain B.

Large mappable areas of plutonic rocks are found in the northwest part of Domain A (the Bonnell Brook Pluton, Unit 12a) and immediately to the north of Domain A, (the Point Wolfe River Pluton). The remainder of Domain A is devoid of large intrusions. Domain B, and to some extent Domain C, contains numerous felsic and mafic intrusions. Those in Domain B are commonly larger and comprise mappable units.

FOLDS AND FABRICS

Most of the rocks in the project area have been affected by a pervasive cataclastic deformation, especially the tuffaceous volcanic rocks, the detrital sedimentary rocks, and the margins of the larger intrusions. In many of the smaller intrusions, however, this deformation is sporadic and occurs in zones a few centimetres to several tens of metres wide. The boundaries between deformed and undeformed zones in the intrusions are gradational.

The cataclastic texture is described in detail by Ruitenberg et al. (1973) and is referred to as the S_1 fabric. The S_1 fabric is generally oriented subparallel to bedding (S_0) but deviates from S_0 in places, revealing first-phase folds. Prominent attitudes of the S_1 fabric in each of the major domains is given in Table 2.

Locally, there is evidence for a pre-S_1 cleavage. On Rapidy Brook, about 1 km from the Bay of Fundy, a pre-existing fabric is terminated and partially overprinted by S_1. Furthermore, the conglomerates in Unit 13a that are deformed by S_1, contain pebbles exhibiting a pre-existing fabric. This fabric will be referred to as S_X.

In addition to S_X and S_1, a second cataclastic-type fabric, generally oriented at shallow angles to S_1, appears to overprint S_1. This fabric (S_{1a}) can rarely be detected in outcrops, but is commonly observed in thin sections. S_{1a} may not be the result of a distinct tectonic episode but rather reflects a complimentary fabric formed nearly simultaneously with S_1 due to minor fluctuations in prevailing local stress fields.

Several types of folds (F_1) are associated with the S_1 cataclastic fabric. The most common types are microscopic shear folds that deform quartz and calcite veins within beds (see Ruitenberg et al. 1973, Figure 10). These small folds can also be detected in many outcrops, but fold axes do not exhibit consistent orientations. These types of folds are present in all the major structural domains.

Mesoscopic shear folds that deform S_0 surfaces are commonly well developed in fine-grained sedimentary rocks in Domain B. The folds are open to close, vary in wave length from a few centimetres to over one metre, and also do not exhibit consistent orientations (see Figure 4-11, Subzone 3, in Ruitenberg et al. 1979). Excellent examples of this type of folding occur at the mouth of Telegraph Brook, Plate 83-35B(R). At this locality, axial surfaces of the folds dip steeply and fold axes plunge shallowly toward the north.

A megascopic shear fold, that has a shallowly north-dipping axial surface and a gently plunging axis, occurs on Martin Head (Plate 83-35B[R]) in Domain C. A similar fold was described near the project area by Ruitenberg et al. (1973, Figure 11). The fold on Martin Head, however, is much larger (several metres wide) and is not as well defined.

Megascopic tight to isoclinal, first-phase folds, occur in Domain A on the upper parts of the Quiddy and Little Salmon rivers, Plate 83-34(R). These folds were detected in thick siltstone units with well-preserved primary sedimentary structures. On the Quiddy River, the folds are nearly isoclinal, have shallow-dipping axial surfaces, and fold axes that plunge shallowly toward the north. The folds in the Little Salmon River section also have shallowly northward-plunging axes but the folds are close to tight and have steep-plunging axial surfaces. Sedimentary structures in the siltstone units indicate that some of the section in Domain A may be overturned.

Tight to isoclinal folds also occur in Domain C, particularly along the shore to the west of Goose River, Plate 83-36(R). These are upright folds that have steep-dipping axial surfaces and gently northeast- or south-plunging axes. The fold symmetries in this section indicate that a major anticlinal structure exists to the north of this locality.

Crenulations (F_2) of the S_1 fabric are well developed in favourable lithologies throughout the project area (see Figure 4-10 of Ruitenberg et al. 1979). A poorly developed fracture cleavage (S_2) is parallel to the axial surfaces of these crenulations at some localities and in many thin sections. An incipient S_2 fabric is commonly observed. Generally, these crenulations and the fabric appear to have random orientations.

TABLE 2

SUMMARY OF STRUCTURAL GEOLOGY

EVENT	FABRIC	FOLDS
D	Well developed locally in Domains B and C	None
D1	DOMAIN A — Well developed throughout (cataclastic): Strike : N.E.–N. Dip : shallow–moderate ; S.E.–E.	DOMAIN A — Microscopic & megascopic sheer folds present throughout; all orientations: Megascopic isoclinal folds developed within units ; shallowly plunging hinge lines, shallow axial planes
		Megascopic close upright folds ; shallowly plunging hinge lines, moderately dipping axial planes
	DOMAIN B — Well developed throughout (cataclastic): Strike : N.E.–N.N.E Dip : moderate–steep ; N.W. – W.N.W.	DOMAIN B — Microscopic & megascopic sheer folds present throughout; all orientations: No megascopic folds observed
	DOMAIN C — Well developed throughout (cataclastic): Strike : N.E. Dip : steep–horizontal (northern part)	DOMAIN C — Microscopic & megascopic sheer folds present throughout; all orientations: Megascopic shear folds ; shallowly plunging hinge lines
	DOMAIN C — Well developed throughout (cataclastic): Strike : N.E.–E. Dip : moderate–steep ; S.E. (southern part)	DOMAIN C — Microscopic & megascopic sheer folds present throughout; all orientations: Megascopic upright isoclinal folds ; shallowly plunging hinge lines, steeply dipping axial planes
D1a	Poorly developed locally in all zones (cataclastic); generally oriented at small angles to S_1	None
D2	Poorly developed locally in all zones (fracture cleavage); all orientations	Well developed locally as crenulations of S_1 surfaces ; all orientations
D3	None	Megascopic, broad, open folds ; shallowly plunging S.W.
		Microscopic and mesoscopic kinks ; shallowly and steeply plunging on S_1 surfaces, all orientations ; two generations commonly present
Cataclastic fabrics, shear zones and folds related to major faults		

One, and commonly two, generations of kink bands, that deform the S_1 foliation, are ubiquitous in the project area. The kink bands generally plunge shallowly toward the northeast or southwest on S_1 surfaces but orientations, on the whole, are not consistent. All scales of open folds with wavelengths of a few centimetres to several kilometres, are defined by S_1 surfaces. Axes of these folds also commonly plunge toward the northeast or southwest. The broad anticlines and synclines in the Goose River and Goose Creek area (Plate 83-36[R]) are considered to be related to this deformation episode.

Many structures (folds and shear zones) are related to faults throughout the project area. These structures occur in a variety of orientations and sizes and have not been studied in detail.

FAULTS

Numerous major and minor, northeast-, north-, and east-trending faults and complex fault zones occur in the project area (Figure 7 and Plates 83-34[R], 83-35A[R], 83-35B[R], and 83-36[R]). The major structures are northeast-trending faults that are several kilometres in length and dip either at moderate angles to the north (thrust faults) or are subvertical (strike-slip faults).

The Cradle Brook - Walton Brook Fault is one of the major northeast-trending thrust faults. It is the dominant structure in the project area and separates Domain A from B and C. Mainly subaerial felsic and mafic volcanic rocks of Domain A are thrust over rocks of possible Cambrian age and over subaqueous mafic and felsic volcanic rocks of Precambrian age in the Cradle Brook and Walton Brook areas respectively (McLeod and McCutcheon 1981). Rocks below the fault are intensely sheared and complexly folded over several tens of metres. The fault is well exposed on shore sections near Cradle Brook (Figure 8); however, it is poorly exposed inland, generally occurring as a broad shear zone. North of Walton Brook, the fault may change strike and trend east-west to form the southern contact of Unit 10.

Several smaller north-dipping thrust faults and splays of the Cradle Brook-Walton Brook Fault occur south of the main fault trace. A splay of the major fault is well exposed 1.5 km east of Cradle Brook. Large blocks of highly deformed Cambrian strata up to 2 m in diameter are incorporated in the shear zone that is over 20 m wide at this locality.

Structural relationships are particularly clear along the small thrust fault 0.5 km east of Wolf Brook, Plate 83-35B(R). Above the thrust, the regional tectonic fabric and bedding appear to be unaffected by the faulting. Below the thrust, a shear zone about 15 cm wide that is oriented parallel to the fault has overprinted the pre-existing fabric. Below this shear zone, mesoscopic folds with nearly horizontal hinge lines deform the regional tectonic fabric and exhibit an incipient steep-dipping axial surface cleavage.

The major faults that bound Domains B and C and many of the minor faults in these areas, may be part of a sinistral strike-slip fault system. About 2 km of left-lateral movement is postulated along the Wolf Brook Fault. Similarly, sinistral movement of greater magnitude can be postulated along the Rose Brook Fault (Figure 7). The strike-slip nature of this fault zone as a whole may be demonstrated by the overall fault pattern as shown in Figure 7. Small blocks bounded by faults that formed at acute angles to the dominant faulting direction, and that contain rocks of various ages, are characteristic of major strike-slip fault zones (Wilcox *et al.* 1973).

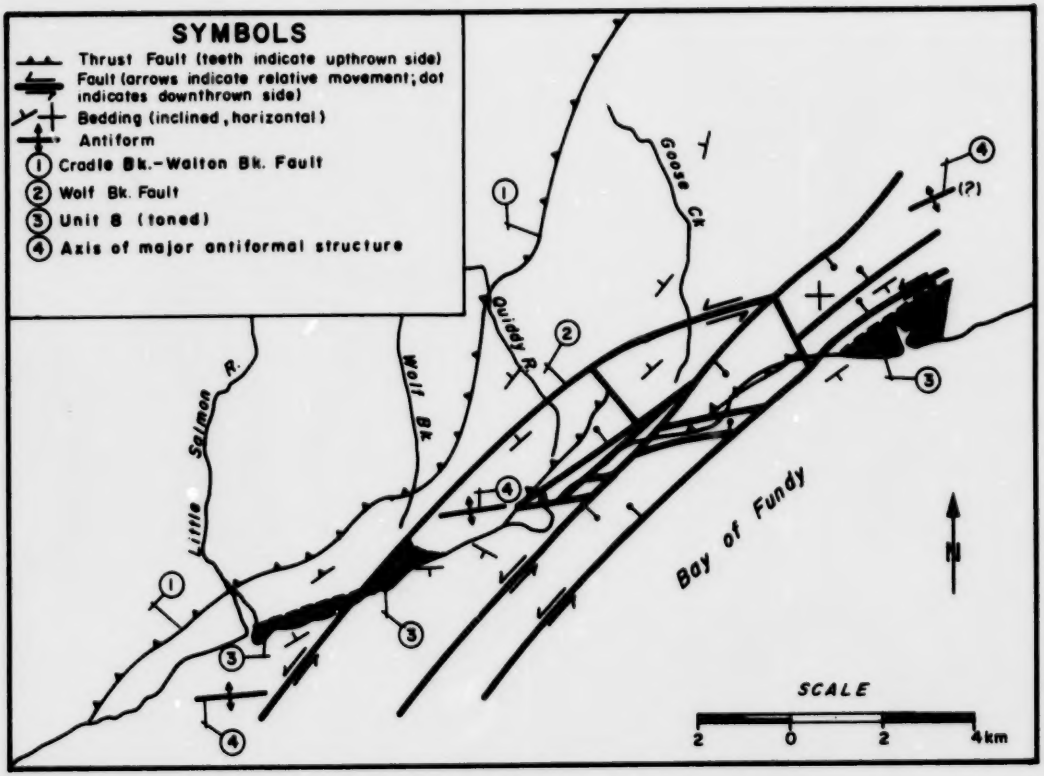


FIGURE 7. Major fault systematics in the project area.

FIGURE 8. Cradle Brook-Walton Brook fault zone, east of Cradle Brook.

Other major faults in the project area are generally steep-dipping and some of these may also be strike-slip faults. The Seely Beach Brook and Little Salmon River faults (Plates 83-35A[R], 83-35B[R]) may have a significant component of dextral strike-slip movement.

SUMMARY OF DEFORMATION

A summary of the fabrics and folds related to the deformation events, represented by D, is given in Table 2. The major antiformal structure that was first noticed by Bailey (1865) and later described by Kindle (1962) and Ruitenberg et al. (1973,1979), is readily apparent in the summary of D_1 fabrics in Domains B and C (Table 2). The position at the axis of this antiformal structure is difficult to determine because of later faulting, but it must pass through Unit 13 in the northern part of Domain C.

The origin of deformation in the project area remains problematical, particularly the formation of the pervasive cataclastic foliation (S_1). Ruitenberg et al. (1973) attributed the cataclastic deformation to an upwarping or bending that produced flattening and shearing under lithostatic load. However, west of the map area, near Saint John, Rast and Grant (1973) suggested that the cataclasis resulted from thrusting that was related to Variscan tectonism. The latter explanation cannot be valid in the project area since the Carboniferous rocks near Martin Head are unaffected by cataclasis.

The age of deformation is also uncertain but some general deductions can be made. The presence of deformed volcanic fragments in rocks of probable Early Cambrian age and the unconformity at the base of these rocks indicate that some deformation took place during the Precambrian. The rocks of probable Early Cambrian age, however, are cataclastically deformed and rocks of Late Mississippian-Early Pennsylvanian age within the project area are not. Also, granitoid rocks of probable latest Precambrian age are affected by the cataclasis. Therefore, the main deformation could have occurred in

the Middle Ordovician Taconian and/or Middle Devonian Acadian orogenies. Ruitenberg and McCutcheon (1982) favour the latter possibility. Critical to constraints on timing of the deformation is the age of the undeformed and discordant diabase dykes. If these dykes are Silurian or Early Devonian in age similar to dykes in Paleozoic rocks to the west, then the deformation must be Taconian.

Relative ages of the major faulting events in the project area can be established with some certainty. Strike-slip faults offset the Cradle Brook-Walton Brook Fault (thrust) in the Cradle Brook area (Plates 83-35A[R], 83-35B[R]) and truncate the small thrust fault at the mouth of the Quiddy River. The north- and northwest-trending faults, respectively, appear to pre-date and post-date the other faulting events.

The absolute ages of the faulting events are uncertain. Rocks of Lower Cambrian age are affected by the thrust faults and therefore these faults must have occurred in post-Cambrian time (McLeod and McCutcheon 1981). It is possible that these faults reflect the Acadian Orogeny during which the Avalon and Meguma blocks collided (Ruitenberg and McCutcheon 1982).

The strike-slip faulting event probably occurred during Carboniferous time since rocks of Carboniferous age are affected. Carboniferous faulting events including strike-slip faulting, are well documented in southern New Brunswick (McLeod 1979a; Ruitenberg and McCutcheon 1982). Most of this faulting was probably related to movements along the Minas Geofracture (Arthaud and Matte 1977). The disposition of the Triassic strata in the project area indicates that some later faulting occurred during Triassic time.

PETROCHEMISTRY

A limited number of samples (43) of the igneous rocks in the project area was collected to assess the chemical variation within and between the major intrusive and extrusive igneous units. The samples were analysed at X-Ray Laboratories, Toronto (Table 3). Averages and standard deviations are shown on Table 4. Sample locations and a list of the rocks that were analysed are given in Figure 9. Analyses were done by XRF except FeO and H_2O^+ that were done by wet chemical methods. Accuracy and precision of standards submitted are shown on Table 5.

Samples selected for chemical analysis were the freshest available. All rocks in the project area, however, have been affected to some extent by the regional greenschist facies metamorphism. In the felsic rocks, plagioclase is intensely saussaritized, biotite is partially to totally chloritized and the matrix shows some recrystallization and development of secondary muscovite. The mafic rocks exhibit greater alteration effects. Mafic minerals are commonly chloritized and epidotized and often are totally obliterated. The matrix of these rocks is always totally chloritized.

MAFIC INTRUSIONS

Several samples representative of gabbroic and diabasic intrusions in the project area were analysed (analyses 24-37). There is, however, no apparent systematic variation of elements in these rocks, with respect to relative age or distribution.

In general, the mafic intrusions are subalkaline, are orthopyroxene and quartz or olivine normative (no modal olivine is present), and exhibit a moderately strong iron-enrichment trend on the AFM diagram (Figure 10). These features indicate that these rocks are tholeiites that are saturated or slightly undersaturated. The similarity in chemical composition of this suite of rocks suggests prolonged, episodic mafic magmatism from a common source in this area.

TABLE 3
CHEMICAL ANALYSES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
SiO_2	79.5	80.0	77.0	75.8	77.1	73.3	72.5	71.0	71.8	73.8	66.1	64.1	65.2	67.6	76.2	73.1	71.9	72.2	75.7	77.5	76.2
TiO_2	0.05	0.05	0.05	0.05	0.07	0.34	0.39	0.09	0.40	0.32	0.52	0.50	0.51	0.36	0.12	0.32	0.34	0.37	0.23	0.20	0.31
Al_2O_3	10.8	10.9	12.2	11.6	12.0	13.1	13.6	13.1	13.7	13.2	14.8	14.8	15.3	15.8	11.1	13.8	14.0	12.6	11.3	11.3	12.2
Fe_2O_3	0.27	0.75	0.68	0.61	0.41	0.57	1.64	1.78	1.27	1.45	1.66	1.78	1.30	2.41	0.43	0.99	1.57	0.75	0.97	0.50	1.23
FeO	0.4	0.1	0.3	0.3	0.8	1.0	1.2	1.0	1.7	1.3	1.7	1.6	2.2	0.9	1.0	0.8	0.5	2.3	1.4	1.6	0.6
MnO	0.02	0.01	0.01	0.02	0.04	0.05	0.07	0.05	0.06	0.06	0.07	0.05	0.06	0.08	0.04	0.05	0.07	0.06	0.07	0.04	0.03
MgO	0.00	0.00	0.05	0.12	0.50	0.68	0.97	0.82	0.75	0.76	1.59	1.38	1.77	0.99	0.06	0.76	0.54	1.43	0.66	2.33	0.72
CaO	1.08	0.33	0.91	1.65	0.94	2.25	3.01	2.75	2.41	2.28	2.95	4.49	1.75	3.93	0.53	1.69	2.25	1.01	1.27	0.45	2.60
Na_2O	2.24	3.35	2.73	2.54	3.95	3.09	3.87	2.77	4.16	3.60	4.45	3.28	3.77	4.15	3.53	3.53	3.94	5.03	4.65	3.11	5.32
K_2O	4.18	3.63	4.60	3.98	3.12	2.39	1.36	2.47	1.50	2.29	1.85	3.57	3.54	1.48	3.44	3.24	2.90	0.50	0.64	0.98	0.12
P_2O_5	0.01	0.01	0.01	0.02	0.02	0.06	0.07	0.07	0.08	0.07	0.12	0.11	0.13	0.17	0.02	0.08	0.08	0.06	0.04	0.93	0.05
H_2O^+	0.2	3.2	0.5	0.5	0.6	1.4	1.2	1.1	1.0	0.9	1.2	1.1	1.4	0.9	0.4	0.9	0.7	1.1	0.6	1.6	0.4
TOTALS	98.75	102.35	99.44	97.09	99.55	99.23	99.88	97.30	98.83	100.03	97.01	96.76	96.93	98.77	96.87	99.26	98.79	97.41	97.53	99.64	99.78
Q	48.80	46.29	42.27	43.80	39.86	41.22	37.43	39.87	36.34	38.35	25.56	21.99	24.38	28.40	42.70	36.08	32.98	37.83	43.77	52.07	39.12
C	0.70	0.88	1.09	0.33	0.49	1.51	0.44	1.04	1.04	0.86	0.42		2.47	0.65	0.68	1.64	0.52	2.18	0.72	4.49	
Or	25.09	21.65	27.48	24.34	18.59	14.37	8.12	15.13	9.03	13.61	11.34	21.96	21.78	8.92	21.04	19.44	17.41	3.08	3.92	5.88	0.73
Ab	19.23	28.55	23.36	22.22	33.71	26.64	33.00	24.25	35.82	30.57	39.04	28.79	33.18	35.70	30.91	30.31	33.85	43.98	40.45	26.76	45.17
An	5.32	1.55	4.47	7.84	4.56	10.97	14.57	13.63	11.65	10.94	14.38	15.81	8.14	18.72	2.62	7.99	10.86	4.80	6.19	2.06	9.17
Cpx												5.39									2.74
Opx			0.14	0.31	1.28	1.97	2.74	2.40	2.35	2.25	4.91	1.78	5.68	3.77	.18	1.99	1.50	4.48	1.92	6.12	0.58
Ol																					
Mt						2.12	2.76	2.55	2.61	2.65	3.04	3.01	3.04	2.74			0.61	2.80	2.23	1.40	
Il	0.05	0.02	0.03	0.05	0.09	0.65	0.75	0.76	0.78	0.01	1.03	0.99	1.02	0.70	0.09	0.44	0.65	0.73	0.45	0.39	0.49
Hm	0.76	0.95	1.10	1.05	1.35	0.41		0.19							1.64	1.85	1.44		0.24	0.76	1.82
Ap	0.03	0.03	0.03	0.03	0.05	0.15	0.17	0.18	0.18	0.16	0.29	0.27	0.31	0.40	0.04	0.18	0.18	0.13	0.10	0.07	0.12
Ru	0.02	0.06	0.03	0.03	0.03										0.08	0.10					0.06
An%	21.1	5.16	16.1	26.1	11.9	29.2	30.6	36.0	24.5	28.5	26.9	35.4	19.7	34.7	7.82	20.9	24.3	9.85	13.3	7.15	16.9
DI	93.2	96.6	93.2	90.4	92.3	38.5	78.8	79.5	81.5	82.8	76.4	73.2	79.9	73.5	94.8	86.0	84.5	85.3	88.4	85.0	85.2
Rb	160	80	170	150	90	60	40	90	50	40	40	140	130	40	80	90	80	20	20	20	20
Sr	50	40	40	50	40	110	120	70	100	80	380	320	200	430	40	180	190	60	50	30	240
Zr	70	100	90	90	90	120	150	130	130	90	180	150	160	210	240	170	190	130	150	140	110

TABLE 3 (Continued)

	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
SiO_2	74.8	77.5	49.0	47.8	47.5	45.8	45.6	46.6	54.0	48.3	47.7	54.3	51.6	50.6	48.1	47.5	49.7	49.6	51.4	56.5	55.1	52.3
TiO_2	0.26	0.26	1.44	1.06	0.68	1.25	1.28	1.22	1.00	0.89	0.65	0.80	1.66	1.62	2.10	1.14	1.70	0.96	0.94	0.60	0.54	0.64
Al_2O_3	11.6	12.3	14.0	15.3	18.1	21.9	16.1	17.4	15.0	17.7	15.0	16.9	13.7	15.1	13.5	16.0	16.3	18.2	18.0	14.1	13.7	13.2
Fe_2O_3	0.84	0.84	4.80	3.90	3.04	5.08	3.6	3.41	3.87	2.48	1.82	2.16	3.00	4.00	6.00	4.80	5.3	3.16	3.09	1.24	0.89	1.88
FeO	2.5	0.9	7.9	6.5	5.0	4.8	7.8	5.5	5.6	6.1	8.0	5.2	9.3	6.9	9.6	7.4	5.4	5.4	5.8	5.1	4.6	4.7
MnO	0.11	0.04	0.25	0.18	0.16	0.17	0.22	0.18	0.20	0.20	0.21	0.16	0.32	0.21	0.32	0.27	0.19	0.23	0.23	0.15	0.14	0.13
MgO	0.52	0.52	6.17	3.11	7.55	3.70	7.56	8.28	5.05	6.48	12.1	4.53	5.43	5.05	5.59	7.63	4.07	6.78	5.06	6.30	5.35	8.25
CaO	1.08	1.30	8.98	9.40	11.9	11.5	9.16	8.39	5.28	10.8	9.39	7.08	8.32	8.15	7.50	9.67	8.63	7.27	4.47	5.30	7.03	6.87
Na_2O	4.50	4.88	2.65	2.01	1.00	1.63	2.48	2.63	3.86	1.29	1.18	3.65	3.27	2.51	2.33	2.07	2.08	3.49	4.69	5.03	5.58	2.90
K_2O	0.13	0.74	0.28	0.79	0.23	0.51	0.44	0.40	0.11	0.74	0.27	1.29	0.12	0.68	0.47	0.53	0.18	1.82	0.56	0.05	0.04	0.11
P_2O_5	0.05	0.04	0.25	0.18	0.12	0.06	0.24	0.07	0.07	0.04	0.04	0.19	0.14	0.51	0.34	0.18	0.28	0.19	0.19	0.07	0.06	0.06
H_2O^+	0.9	0.8	2.1	2.6	2.7	2.4	2.6	3.1	3.2	2.2	3.7	2.5	2.7	2.5	3.0	0.5	2.8	2.6	2.0	2.6	2.4	3.8
TOTALS	97.29	100.12	97.82	97.83	97.98	98.80	97.08	97.28	97.83	97.32	100.06	98.76	99.56	97.83	98.85	97.69	96.63	99.70	96.43	97.04	95.43	94.84
Q	45.98	43.00	2.36		3.73	1.34			8.40	4.52		5.56	4.91	7.62	3.99		11.04		1.40	6.42	2.66	8.53
C	2.28	1.25																	2.15			
Or	0.78	4.41	1.69	4.87	1.44	3.12	2.73	2.50	0.68	4.55	1.62	7.85	0.70	4.18	2.88	3.18	1.13	10.99	3.45	0.29	0.26	0.71
Ab	39.41	41.45	23.24	17.72	8.84	14.18	21.98	23.44	34.22	11.36	10	31.89	28.30	22.08	20.38	17.92	18.56	30.16	41.73	44.80	50.37	26.79
An	5.21	6.21	26.34	31.62	46.08	52.50	33.19	36.12	24.46	42.09	35.95	26.78	22.83	29.06	25.79	33.44	36.56	29.29	21.95	16.53	13.10	24.72
Cpx			15.12	12.90	11.84	5.01	10.58	5.30	1.56	10.67	9.58	6.73	15.43	7.90	8.72	11.87	5.63	5.17		8.67	19.22	9.71
Opx	3.08	1.36	23.38	25.34	23.11	17.17	13.66	19.23	24.51	21.18	35.12	15.72	19.60	19.99	27.89	22.52	18.07	3.84	23.26	18.70	9.40	24.70
Ol				1.14			10.50	6.40			2.86					4.55		14.58				
Mt	2.64		4.43	3.87	3.30	4.11	4.22	4.15	3.79	3.62	3.21	3.44	4.68	4.71	5.40	3.91	4.90	3.65	3.72	3.21	3.16	3.38
Il	0.50	0.40	2.84	2.11	1.35	2.44	2.54	2.44	1.98	1.77	1.27	1.56	3.62	3.21	4.13	2.21	3.41	1.87	1.87	1.21	1.10	1.32
Hm		1.77																				
Ap	0.12	0.10	0.61	0.43	0.30	0.13	0.59	0.40	0.40	0.33	0.10	0.47	0.33	1.24	0.80	0.42	0.69	0.44	0.48	0.16	0.14	0.14
Ru		0.05																				
An%	11.7	13.0	53.1	67.4	83.9	78.7	60.2	60.6	41.7	78.7	77.7	45.6	44.7	56.8	55.9	65.1	66.3	49.3	34.5	26.9	20.6	48.0
Di	86.7	89.1	28.7	23.0	14.8	19.7	25.0	26.2	44.6	21.4	12.0	46.3	35.4	35.2	29.0	21.4	32.0	41.5	47.8	52.4	54.1	36.9
Rb	10	30	20	40	10	20	20	20	70	20	20	30			20	10	10	70	10		10	10
Sr	40	80	190	190	190	430	230	240	120	180	110	450	130	230	220	190	220	450	410	60	60	60
Zr	180	180	110	160	60	70	70	110	100	80	20	30	100	230	110	90	150	80	70	40	40	40

TABLE 4

AVERAGES AND STANDARD DEVIATIONS OF INTRUSIVE AND EXTRUSIVE ROCKS

	Leucogranite n = 5	Granite Goose Creek n = 5	Granodiorite Bonnell Bk. n = 4	Keratophyre n = 4	Rhyolite n = 3	Diabase and Gabbro n = 14	Mafic Volc. Domain A* n = 6	Mafic Volc. Domains B & C* n = 5
SiO_2 (%)	77.9 ± 1.6	72.5 ± 1.0	65.8 ± 1.3	75.4 ± 2.0	73.7 ± 1.8	48.9 ± 2.7	51.5 ± 3.7	53.6 ± 1.9
TiO_2	0.05 ± 0.00	0.31 ± 0.11	0.47 ± 0.07	0.28 ± 0.07	0.26 ± 0.10	1.20 ± 0.39	1.22 ± 0.28	0.82 ± 0.31
Al_2O_3	11.5 0.58	13.3 0.1	15.2 0.4	11.8 0.6	13.0 1.3	16.1 2.1	17.3 1.4	15.1 1.9
Fe_2O_3	0.54 0.18	1.34 0.42	1.79 0.40	0.86 0.27	1.00 0.51	3.71 1.14	4.31 1.12	2.46 1.54
FeO	0.4 0.2	1.2 0.3	1.6 0.5	1.5 0.6	0.8 0.2	6.8 1.5	5.5 1.3	5.2 0.5
MnO	0.02 0.01	0.06 0.01	0.07 0.01	0.05 0.02	0.05 0.01	0.22 0.05	0.20 0.03	0.17 0.04
MgO	0.13 0.19	0.80 0.10	1.43 0.29	1.28 0.68	0.45 0.29	6.30 2.19	5.61 1.67	6.36 1.14
CaO	0.96 0.39	2.54 0.29	3.28 1.04	1.33 0.79	1.49 0.72	8.97 1.68	7.53 1.64	5.99 0.97
Na_2O	2.96 0.74	3.50 0.51	3.91 0.44	4.53 0.85	3.67 0.19	2.33 0.85	3.04 0.63	4.32 1.01
K_2O	3.90 0.50	2.00 0.47	2.61 0.95	0.56 0.31	3.19 0.22	0.49 0.32	1.02 0.59	0.17 0.19
P_2O_5	0.01 0.00	0.07 0.00	0.13 0.02	0.27 0.38	0.06 0.03	0.17 0.13	0.20 0.08	0.09 0.05
H_2O^+	1.0 1.1	1.1 0.2	1.2 0.2	0.9 0.5	0.7 0.2	2.6 0.7	2.7 **	2.7 **
TOTAL	99.39	98.76	98.12	98.76	98.34	97.79	100.16	97.98
				trace elements (ppm)				
Rb	130 ± 37	60 ± 19	90 ± 42	20 ± 00	80 ± 6	20 ± 15	40 ± 22	10 ± 2
Sr	40 6	100 19	330 76	100 76	140 68	220 89	270 81	190 126
Zr	90 10	120 20	180 21	130 13	200 29	100 51	140 36	70 43

NOTES:

n = number of analyses averaged

* Includes relevant analyses from Ruitenberg et al. (1979)

**Analyses from Ruitenberg et al. (1979) were not analysed for H_2O+

TABLE 5

ANALYTICAL PRECISION AND ACCURACY USING INTERNATIONAL STANDARDS

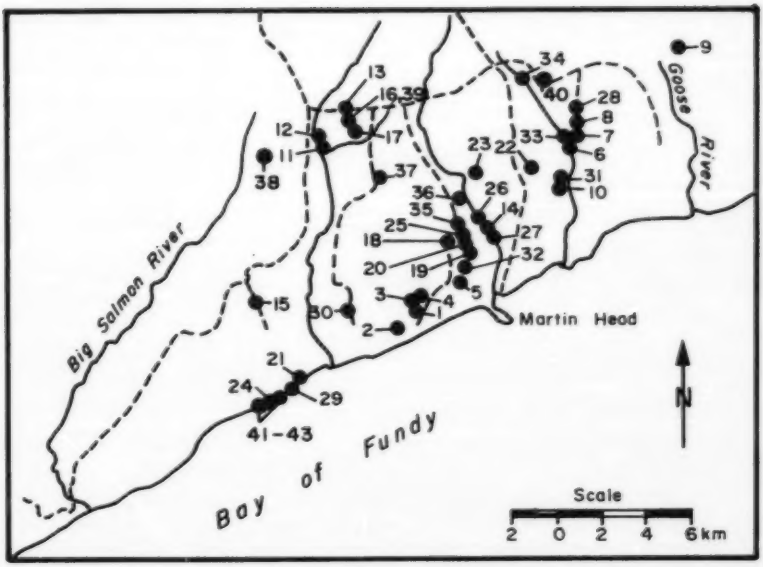
	AGV - 1		GSP - 1		G2		CRPG BR		CRPG GA	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)*	(2)
SiO_2 (%)	58.5	59.61	65.5	67.32	68.4	69.22	37.9	38.39	69.5 ± 0.4	69.96
TiO_2	1.05	1.06	0.66	0.66	0.49	0.48	2.64	2.61	0.37 ± 0.00	0.38
Al_2O_3	17.0	17.19	14.7	15.28	15.0	15.40	10.1	10.25	14.7 ± 0.1	14.51
Fe_2O_3	4.72	4.56	1.66	1.70	1.15	1.07	5.10	5.61	1.42 ± 0.10	1.36
FeO	1.7	2.03	2.1	2.32	1.1	1.44	6.3	6.60	1.1 ± 0.1	1.32
MnO	0.11	0.10	0.04	0.04	0.04	0.03	0.21	0.20	0.09 ± 0.00	0.09
MgO	1.49	1.52	0.99	0.97	0.75	0.75	13.2	13.35	0.94 ± 0.01	0.95
CaO	4.82	4.94	2.04	2.03	1.98	1.96	13.2	13.87	2.51 ± 0.02	2.45
Na_2O	4.08	4.32	2.62	2.81	3.85	4.06	2.83	3.07	3.37 ± 0.02	3.55
K_2O	2.74	2.92	5.20	5.51	4.15	4.46	1.33	1.41	3.78 ± 0.09	4.03
P_2O_5	0.50	0.51	0.28	0.28	0.14	0.13	1.05	1.05	0.13 ± 0.00	0.12
H_2O^+	1.0	0.78	0.2	0.58	0.5	0.50	2.5	2.31	0.7 ± 0.00	0.87
					trace elements (ppm)					
Rb	60	67	200	250	130	170	50	47	150 ± 10	175
Sr	530	660	180	240	390	480	1020	1300	240 ± 00	310
Zr	200	230	500	500	290	300	280	250	120 ± 10	150

NOTES:

(1) Analyses by X-Ray Assay Laboratories

(2) Usable Values for standards (Abbey 1983)

*Run in duplicate



1. slightly fractured leucogranite
2. massive leucogranite
3. massive leucogranite
4. massive leucogranite
5. massive leucogranite
6. massive granite
7. massive granite
8. cataclastic granite
9. massive granite
10. massive granite
11. massive granodiorite
12. massive granodiorite
13. cataclastic granodiorite
14. cataclastic granodiorite
15. massive, rhyolitic flow
16. porphyritic rhyolite (dyke?)
17. slightly porphyritic rhyolite (dyke?)
18. cataclastic, keratophyre porphyry
19. massive, keratophyre porphyry
20. cataclastic, keratophyre porphyry
21. massive, keratophyre porphyry
22. massive low-K granite
23. massive low-K granite
24. massive, porphyritic diabase
25. massive diabase
26. massive, porphyritic diabase
27. massive diabase
28. cataclastic diabase
29. cataclastic diabase
30. cataclastic diabase
31. massive, porphyritic gabbro
32. massive gabbro
33. massive gabbro
34. cataclastic gabbro
35. slightly cataclastic gabbro
36. cataclastic gabbro
37. cataclastic gabbro
38. vesicular basalt
39. vesicular basalt
40. basaltic breccia
41. pillow lava
43. pillow lava

FIGURE 9. Location map and a brief description of analysed samples.

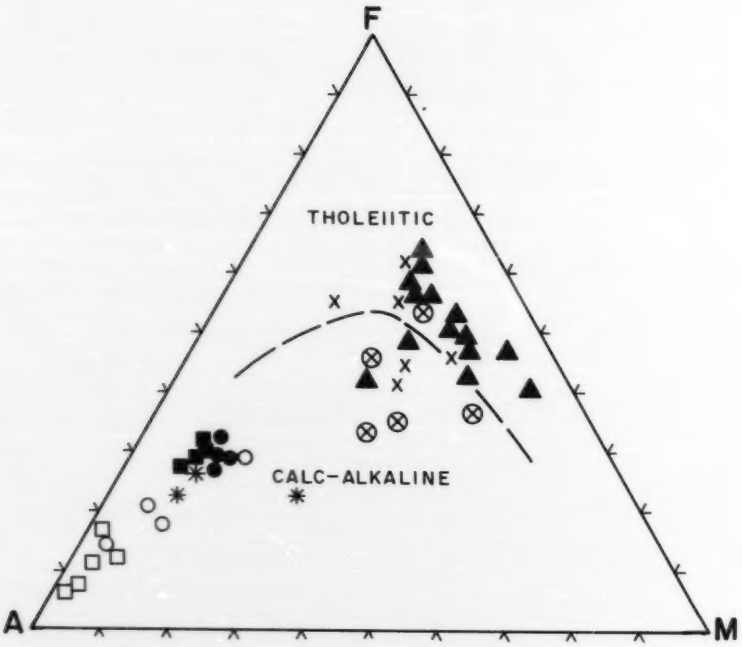


FIGURE 10. AFM diagram for the intrusive and extrusive rocks. Boundary line after Irvine and Baragar (1971). Includes analyses from Ruitenberg et al., 1979. Open squares = leucogranite; solid squares = granite (Goose Creek); solid circles = granodiorite (Bonnell Brook); solid triangles = mafic intrusive rocks; crosses = mafic extrusive rocks. Circled crosses are mafic extrusive rocks from south of the Cradle Brook-Walton Brook Fault; circles = keratophyre; asterisks = rhyolites.

FELSIC INTRUSIONS

Two chemically distinct types of granitoid rocks occur in the project area. One type is represented by the leucogranites (Unit 12c) that occur along the Wolf Brook Fault (analyses 1-5) and the other is represented by the granites and granodiorites (Unit 12b, analyses 6-10, and Unit 12a, analyses 11-14). Modal analyses of numerous samples collected from the Bonnell Brook Pluton, show a broad scatter within the granite and granodiorite field (Ruitenberg et al. 1979). These major groups are readily distinguished in the AFM diagram (Figure 10). Trace element abundances (Rb, Sr, and Zr) in the two groups are also quite distinctive (Table 3). Two analyses (analyses 22-23) are also given for the low-K granites in the Goose Creek area.

The granitoid intrusions are subalkaline and exhibit typical calc-alkaline trends (Figures 10 and 11). The leucogranite intrusions (Unit 12c) are highly differentiated with high K_2O/Na_2O and Rb/Sr ratios, and low TiO_2 contents relative to the granodiorites (Units 12a and 12b).

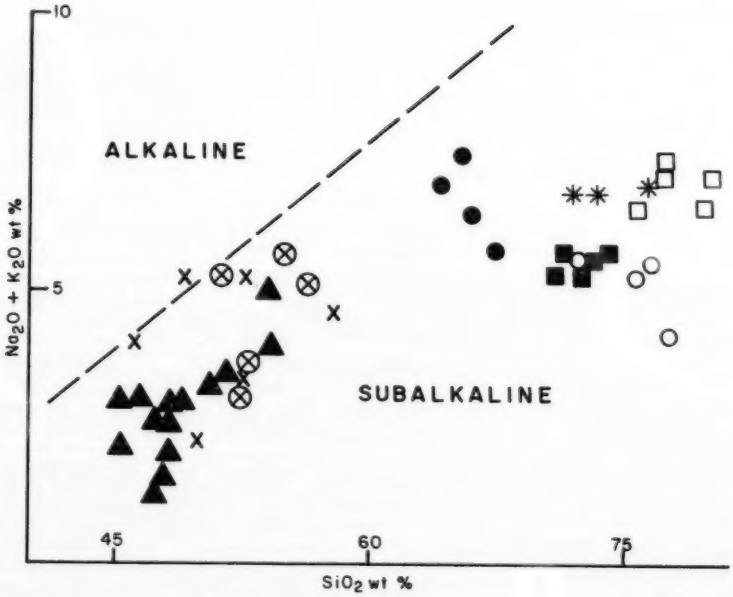


FIGURE 11. Alkalies - silica diagram for the intrusive and extrusive rocks. Boundary line after Irvine and Baragar (1971). Includes analyses from Ruitenberg et al. 1979. Symbols as in Figure 10.

The fine-grained felsic intrusions occur in two chemically distinct groups. The felsic porphyries in Zone B near Wolf Brook (Unit 12e; analyses 18-20) and near Cradle Brook (analysis 21) are high in sodium, low in potassium, and are probably keratophyres as described by Hughes (1973). The fine-grained felsic rocks and porphyries in Domain A (analyses 15-17), however, appear to be normal rhyolites (see Carmichael et al. 1974). Both groups are subalkaline and exhibit a typical calc-alkaline trend (Figures 10 and 11).

MAFIC FLOWS

Ruitenberg et al. (1979) analysed mafic flows from the Caledonia area and concluded that the basalts were oversaturated to slightly undersaturated. Only one of these samples (Analysis 21; Ruitenberg et al. 1979, page 130) was taken south of the Cradle Brook - Walton Brook Fault. Other samples (Analyses 12, 13, 14, 15; Ruitenberg et al. 1979, page 130) were taken north of the fault. In this study, analyses 38 and 39 were taken north, and analyses 40-43 were taken south of the fault respectively.

The mafic flows to the north of the Cradle Brook - Walton Brook Fault are mainly basaltic in composition but those to the south are andesites or basaltic andesites. The flows are subalkaline (Figure 11) but problems are encountered when attempting to classify these rocks further. The flows south of the fault plot in the calc-alkaline field on Figure 10, whereas some of those to the north plot in the tholeiitic field and

show some iron enrichment. The relatively high TiO_2 and Zr content of mafic rocks north of the fault suggests continental affinities for these rocks (Gale and Pearce 1982). The mafic volcanic rocks to the south have a lower content of these elements.

In summary, it appears that the mafic volcanic rocks south of the fault are calc-alkaline and that those to the north are tholeiitic with continental affinities. This conclusion is consistent with field evidence that indicates a major division of the project area into deposits formed mainly in the subaerial environment and a subaqueous environment north and south of the Cradle Brook - Walton Brook Fault, respectively.

ECONOMIC GEOLOGY

The project area contains numerous small vein and strata-bound (?) types of copper, zinc, and lead base-metal sulphide occurrences. These deposits have been known to exist in the project area since the late 1800's. Some of the deposits were mined for copper in the mid and late 1800's, including the Vernon Copper Mine that is located 1 km east of Goose Creek (Plate 83-36[R]), the Martin Head Prospect that occurs on the west side of the Quiddy River near Martin Head (Plate 83-35B[R]), and a prospect located on Goose River about 0.5 km from its mouth (Plate 83-36[R]). Little information is available for the Goose River and Martin Head prospects. The Quiddy River and Goose Creek prospects are part of a broad mineralized belt located in the northeastern part of Domain B. The Shear Brook Prospect is located south of the Goose Creek Prospect. A small gypsum deposit occurs in a fault zone near Martin Head.

VERNON COPPER MINE

The Vernon Copper Mine was discovered in the mid 1800's, was mapped by Hind (1865), and was operated by the Saint John and Albert Mining Company in 1864. Bailey (1865) provides a detailed account of mining operations at that time.

The mineralized zone is situated in fine-grained felsic tuffaceous rocks of Unit 10 above a major low-angle reverse or thrust fault that bounds Unit 10 and mafic volcanic rocks of Unit 14a. The main ore minerals (chalcopyrite, bornite, and chalcocite) are associated with a thick quartz-calcite vein system called the Peacock Vein by early workers. Bailey (1865) reported that the copper ores also contain small amounts of gold (.34-5.83 g/t or .01-.17 oz./ton) and a nearby gossan assayed 137.14 g/t (4.0 oz./ton) gold.

East Trinity Mines Ltd. (1959) and Centennial Mines Limited (Kirwan 1969) conducted work in the Vernon mine area. Centennial Mines drilled three shallow holes and one deep one through the vein and reported 1.23% copper over 2 m in the first hole. The second hole intersected the vein but it was barren and the third hole did not intersect the vein. The deep hole did not intersect metallic minerals. The company also conducted a soil sampling survey in the area but only a few small copper anomalies were found. Grab samples collected along the shore beneath the adit contain significant amounts of copper sulphides.

Whaley (1981, 1984, and 1985a) has studied the mine area in considerable detail for its gold potential. He conducted geological and geochemical surveys followed up by trenching (5 trenches) and drilling (4 holes). Whaley (1981) estimates the presence of 1-3 million tonnes of 2-3% Cu and .34 g/t (.01 oz./ton). Results from the geochemical surveys are very encouraging with the best assays from rock chips of quartz-carbonate veins yielding 3,000 ppb Au, 34.29 g/t (1.0 oz./ton) Ag, and 3-4% Cu.

The mineralized zone may have limited strike length. Unit 10 is terminated by a northwest-trending fault to the east and the vein material does not appear on Jim Brook, west of the mine. Rocks with malachite staining similar to those at the mine, however, do occur in Unit 10, 0.5 km east of Martin Head.

Another mineralized zone in this area that contains abundant malachite, occurs at the contact between basalt and limestone in Unit 14 and at the contact between limestone of Unit 14 and conglomerate of Unit 16 on the headland, east of Goose Creek, Plate 83-36(R). No assay results are available for this locality.

MARTIN HEAD PROSPECT

The Martin Head Prospect was mentioned by Kindle (1962) who stated that a 10 m shaft was sunk at this locality. No other information on mining at the prospect was recorded.

Malachite and minor amounts of chalcopyrite are associated with arkosic sandstone of Unit 13 near major northeast-trending faults in the vicinity of the shaft.

Whaley (1985b) conducted geological and geochemical surveys on the property. Grab samples assayed 680 ppm Au, 10.6% Cu, and 8.1 ppm Ag. Some soils were also found to be anomalous in gold.

QUIDDY RIVER AND GOOSE RIVER PROSPECTS

Sphalerite and chalcopyrite were discovered in this area by Kindle (1962). The mineralized zone occurs south of the Cradle Brook-Walton Brook Fault in the intercalated felsic and mafic rocks of Unit 9 and the mafic tuffaceous rocks of Unit 6a. Assays of some of the tuffaceous rocks in this area yield trace amounts of gold.

Chalcopyrite is the most abundant metallic mineral in this area, and is commonly associated with quartz-calcite veins (up to 20 cm wide), that fill shear zones and small faults. Assays of grab samples yielded about 1.5% copper. Minor amounts of sphalerite have also been reported in these veins.

Wide (up to 5 m) rusty-weathering pyrite-rich zones, containing minor amounts of disseminated chalcopyrite are present in the Quiddy River and Goose Creek prospects. One assay from grab samples of these zones returned trace amounts of gold. These pyrite-rich zones are laterally continuous and commonly occur in the pale green or white felsic tuffaceous rocks. Disseminated chalcopyrite and bornite are also associated with the laminated pyritiferous siltstones of Unit 9b. These siltstones also contain up to 72 ppb gold.

One occurrence of hydrozincite occurs in Unit 5a on a small tributary of the Quiddy River located 3.2 km from the Bay of Fundy, Plate 83-34(R). The hydrozincite occurs locally in thin (1 cm) discontinuous veins in highly epidotized mafic tuffaceous rocks.

Several prospectors and mining companies, including G.F. Perry (1964), Bay Shore Mining Co. Ltd. (Johnston 1970), Falconbridge Nickel Mines Ltd. (Lockhart 1970), New Jersey Zinc Exploration Ltd. (Millett 1970a), Heath Steele Mines Ltd. (LeHeup 1973), Atlantic Coast Copper Ltd. (Peck 1974), and Campbell Chibougamou Ltée (Lockhart 1980a, b, c) have conducted geophysical and geochemical surveys on the Quiddy River and Goose Creek prospects. Mija Mines Ltd. drilled 8 shallow holes along the Quiddy River and intersected a mineralized quartz vein that assayed 2.35% copper over 77 cm in one drill hole (Fenton 1971). High stream sediment anomalies occur in the vicinity of mineral occurrences in the belt (McLeod 1979b).

Lockhart (1980b) reports silver values in the Quiddy River area in addition to high copper and zinc values. Numerous soil anomalies yielding up to 150 ppm copper and 1380 ppm zinc were found scattered throughout the area. Many of these anomalies and several well-defined electromagnetic and magnetic anomalies appear to follow local structural trends. The largest conductor parallels Walton Brook (along the Cradle Brook-Walton Brook Fault) but other conductors do not appear to be fault controlled. These features and the common occurrence of distinct lithologic units containing sulphides may indicate the presence of large, low-grade stratabound base-metal sulphide mineral deposits in addition to the fault-controlled, vein-type occurrences.

Lambert and Whaley (1981), Lambert et al. (1981a, 1981b) conducted geophysical, geological, and geochemical surveys in the Goose Creek, Upper Goose Creek, and Quiddy River areas. High copper, lead, and zinc anomalies were found in soils of the Quiddy and Upper Goose Creek prospects. Trace amounts of gold were found at the Quiddy River Prospect.

SHEAR BROOK PROSPECT

Minor amounts of chalcopyrite and malachite occur in the Shear Brook area, associated with small quartz-filled shear zones. I.G.O. Fenton (1968) and Moreau, M.J. (1970) (Mija Mines Limited) explored this area. I.G.O. Fenton reported several fairly high copper soil anomalies (about 50-120 ppm copper) and Mija Mines Limited delineated several well-defined electromagnetic conductors. Moreau (1970) also reports float that assayed 5.45% copper. The electromagnetic conductors and some of the soil anomalies appear to follow the local bedding trends and do not appear to be related to faulting.

METALLIC SULPHIDES IN THE COLDBROOK GROUP

In Unit 8:

The siliceous siltstone unit that is intercalated with a variety of felsic volcanic rocks and limestone in Unit 8, is host to a low-grade mineralized zone along the shore in the Little Salmon River - Wolf Brook area (Plates 83-35A[R], 83-35B[R]) and in the Goose River area (Plate 83-36[R]). Very fine grained chalcopyrite, bornite, and pyrite are disseminated throughout the siltstone units, which are usually several metres thick and laterally continuous. The sulphides are concentrated along shear zones and faults in the vicinity of these units. Minor amounts of chalcopyrite are also found in quartz and calcite veins in the felsic tuff units and in wide, rusty-weathering, pyrite-rich zones similar to those described in the Quiddy River Prospect. Assays of grab samples taken from the siltstone units were quite low with a trace of gold. The unit, however, merits detailed sampling.

Soil sediment and magnetometer surveys were carried out by New Jersey Zinc Ltd. (Millett 1970a, 1971) east of Wolf Brook on claims north of the shore exposures, and several small geochemical anomalies were found.

In Unit 4:

One locality containing bornite and chalcopyrite occurs in fine-grained felsic tuffaceous rocks near the base of Unit 4 on Goose River. One assay from this occurrence yielded 91 ppb Au. High stream sediment anomalies (McLeod 1979b) that occur along strike on the west bank of Goose River to the north of this locality, however,, indicate that the mineralized zone may be quite extensive.

EXPLORATION TARGETS

Minor amounts of copper sulphides (mainly malachite staining and chalcopyrite) occur at numerous localities throughout the project area. These minerals generally occur in quartz or calcite veins that commonly fill narrow shear zones, faults, or joints. Examples of this type crop out at the mouth of Rose Brook (Plate 83-36[R]), on the shore west of Little Salmon River (Plate 83-35B[R]), and on Goose River (Plate 83-36[R]).

Small amounts of chalcopyrite and malachite have also been found in the project area in a small granitic plug (Unit 12b) on the Quiddy River, in a small stock on the upper part of the Little Salmon River (Unit 12a), and just south of the leucogranite (Unit 12c) on Goose River. Similar types of occurrences are also observed in the felsic tuffaceous rocks of Unit 1, north of Broad Brook and east of Little Salmon River.

Other areas that have received some attention by mining companies in the project area are the Seely Brook Group of New Jersey Zinc Ltd. (Millett 1970b) and the Little Salmon River Group of Heath Steele Mines Ltd. (LeHeup 1973). New Jersey Zinc Ltd. reported a few small copper and zinc anomalies in the Seely Beach Brook area. Several of these anomalies occur along the trace of the Seely Beach Brook Fault. Heath Steele Mines Ltd. reported low concentrations of copper, lead, and zinc in the soil samples taken from the Little Salmon River area.

STREAM SEDIMENT GEOCHEMICAL SURVEYS

Stream sediment samples were collected on all major streams and rivers in the project area at about 300 m (1000') intervals (Plate 80-22). The samples were sieved to -80 mesh and analysed by the New Brunswick Department of Natural Resources and Energy for copper, lead, zinc, molybdenum, silver, cobalt, nickel, manganese, and iron using atomic absorption techniques. Copper, lead, zinc, and uranium values are published - Plates 80-22A, B, C, and D. Threshold and background values were calculated for the analysed elements but the wide variations in lithology render these values suspect.

Copper, zinc, and some lead anomalies are associated with all the major mineralized zones and several of the smaller occurrences in the project area. Most of the lead anomalies appear to be associated with the fine-grained felsic intrusive rocks. The other elements are fairly uniform throughout the area and very few anomalies were found. One extensive zinc and lead anomaly, that occurs along East Goose Creek, may have been produced by the erosion (along strike) of Unit 5a.

GEOPHYSICAL SURVEYS

A DIGHEM II electromagnetic, magnetic, and resistivity survey was flown over the project area and over two areas east of the project area in the Caledonian Highlands during the fall of 1978. A total of 3951 line kilometres was flown at a 200 m line spacing. DIGHEM Limited produced geophysical maps of the areas at a scale of 1:10 000 and a report summarizing the results (Fraser 1979).

Most of the electromagnetic anomalies in the project area occur north of the Cradle Brook-Walton Brook Fault (Groups A to I, Figure 12) and are either 'x-type responses' (possible anomalies or low-grade anomalies). Two areas near Little Salmon River (Groups A and B, Figure 12), contain several closely spaced 'x-type responses' and low-grade conductors.

Detailed prospecting, ground magnetometer surveys, and soil sampling were conducted over most of the Dighem II electromagnetic anomalies. The 'x-type responses' with a subscript S (or surficial anomaly) were not investigated in detail.

Group A is underlain by fine-grained felsic tuffaceous rocks and minor mafic tuffaceous rocks of Units 1, 1a, and 1c. Only minor amounts of malachite staining and specular hematite occur in the mafic tuffaceous rocks on the steep banks of Little Salmon River. Stream sediments collected near this area gave copper values ranging from 20-39 ppm. A ground magnetometer and preliminary soil geochemical survey yielded little additional information about possible metallic minerals in this

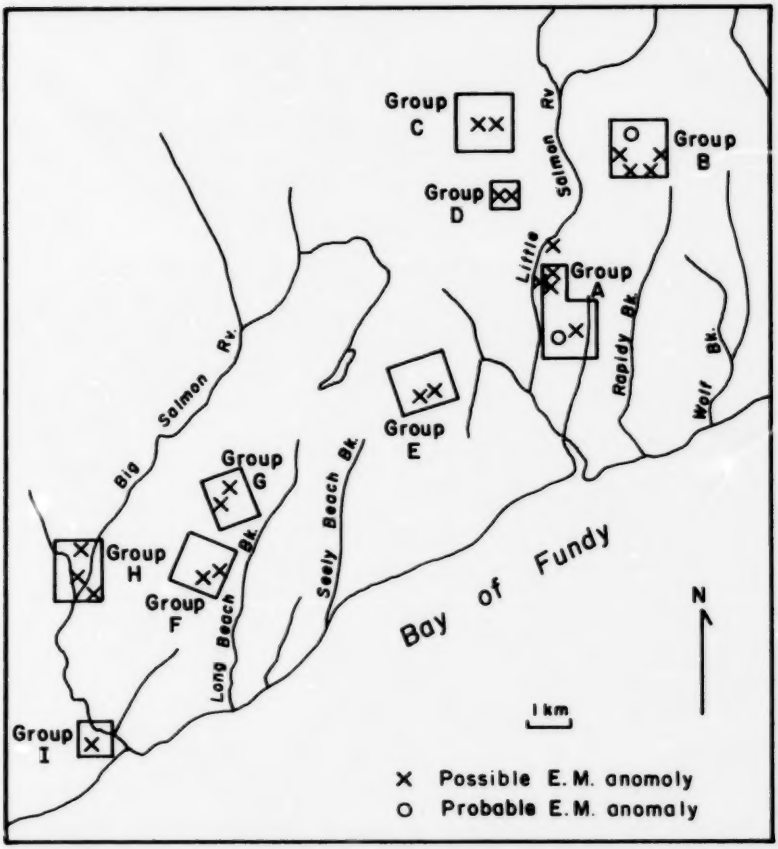


FIGURE 12. Location map for the detailed magnetic and soil sampling surveys.

area. Magnetic highs in the northern part of Group A indicate the presence of underlying mafic volcanic rocks. Copper values (2-5 ppm in soil sediments), are uniformly low in Group A but a few small lead (67 ppm) and zinc (118 ppm) anomalies occur near the low-grade electromagnetic anomaly. Parent (1980) and Hendry (1981) conducted geophysical and geochemical surveys in Group A for Cominco Ltd. but results were not encouraging.

Group B is underlain by felsic and mafic volcanic rocks of Units 1, 1a, 1b, and 2, and by gabbroic rocks of Unit 11. Abundant malachite staining in the float of fine-grained felsic volcanic rocks is present in the west part of Group B, but no

Several groups of 'x-type responses' are present west of Little Salmon River. Detailed ground magnetometer and preliminary soil sampling surveys were conducted over several of these anomalies (Groups C, E, F, and G).

Most of the anomalies occur along the margin of a broad zone of high magnetic response, that is related to the felsic and mafic intrusions of the Bonnell Brook and Point Wolfe River plutons. The electromagnetic anomalies occur in various rock types (Units 1, 2, and 3) and are generally located south of the main intrusive contacts of the plutons. The magnetic map, however, indicates that these plutons may extend at shallow depths beneath some of the electromagnetic anomalies. Outcrops are sparse and no metallic minerals have been found in the vicinity of the electromagnetic anomalies west of Little Salmon River.

The eastern and western parts of Group C are underlain by felsic and mafic volcanic rocks of Units 1 and 2, and by intrusive rocks of Unit 12a, respectively. The detailed magnetic survey delineates this contact accurately. The soil survey indicates a broad band of slightly anomalous zinc (60-90 ppm) and lead (60-113 ppm) values in the vicinity of the electromagnetic anomalies. Background values for copper, lead, and zinc are about 10, 30, and 20 ppm, respectively. Stream sediment samples collected in Broad Brook, east of Group C, however, showed no anomalous metal values. A reconnaissance magnetometer survey and geological mapping indicate that a situation similar to Group C exists in Group D.

Group E contains no outcrops but exposures nearby indicate that the area is underlain by felsic and mafic volcanic rocks of Units 1 and 2. The source of magnetic highs in the northern part of Group E is uncertain but their linear trends and orientation parallel to the local bedding strike indicates that mafic volcanic rocks may predominate in this area. The southern part of Group E exhibits low magnetic response and is probably underlain by relatively homogeneous felsic volcanic rocks. Several magnetic highs are associated with areas of anomalous zinc (60-107 ppm), copper (30-50 ppm), and to a lesser extent, lead values. Anomalous lead (70-114 ppm) and copper (21 ppm) soil sediment values were found in the southern part of Group E. Stream sediments collected on McCumber Brook contained anomalous values of lead and zinc.

Group F is also devoid of outcrops but is assumed to be underlain by felsic and mafic volcanic rocks of Units 1 and 2. A reconnaissance ground magnetometer survey was carried out but little variation in magnetic response was detected. Soil geochemical surveys, however, indicate the presence of anomalous copper (30-128 ppm) and zinc (50-90 ppm) values in the vicinity of the 'x-type responses'.

Group G is well within the broad zone of high aeromagnetic response and is bordered to the north by the intrusive rocks of Unit 12a. The southern and northern parts of Group G are mainly underlain by mafic volcanic rocks of Unit 2 (and minor hornfelsic siltstone) and felsic volcanic rocks of Unit 1 respectively. These units are bounded by a major northeast-trending fault zone that transects Group G. The location of this fault zone is reflected in the ground magnetometer survey. The magnetic highs near this fault zone and south of the fault zone probably reflect the presence of mafic volcanic rocks. Copper, lead, and zinc values from soil sediments collected in Group G are low and show little variation. Two localized zinc anomalies (50-250 ppm), however, are present just north of the major fault zone and correspond with the DIGHEM II responses in Group G.

Two other groups (H and I) containing 'x-type responses' are located in the Big Salmon River area (Figure 12). Those in Group H are situated in the granitoid rocks of Unit 12a. Nearly continuous exposures of granitoid rocks were examined in this area but no metallic minerals were found.

The 'x-type response' near the mouth of Big Salmon River is underlain by felsic volcanic rocks of Unit 1. Several outcrops in the area were examined but no metallic minerals were found. A reconnaissance soil sediment survey in this area, however, indicated the presence of small zinc anomalies (50-105 ppm).

Only a few electromagnetic anomalies are present south of the Cradle Brook-Walton Brook Fault. Two 'x-type responses' occur near the Bay of Fundy shore, between Rapidy and Wolf brooks. These anomalies are in the vicinity of the cupriferous rocks of Unit 8.

Two fairly strong conductors are also present, east of Goose River in Fundy National Park. Although these conductors were not investigated in detail, they are also probably associated with cupriferous rocks equivalent to Unit 8.

SUMMARY AND CONCLUSIONS

The project area is mostly underlain by Precambrian rocks that are divided by faults into three major tectonostratigraphic domains (Domains A, B, and C). Lithological and structural correlations can be made across faults in Domains B and C, but these correlations cannot be extended to Domain A.

The most prominent structural feature - the Cradle Brook-Walton Brook Fault - separates Domain A to the north of the fault from Domains B and C to the south of the fault. The sequence north of the fault is comprised of subaerial and some shallow-water subaqueous volcanic and sedimentary rocks. Most sections are dominated by intercalated felsic and mafic volcanic rocks. South of the fault, on the other hand, the sequence contains subaqueous volcanic and sedimentary rocks. Most sections south of the fault are dominated by mafic volcanic rocks. This contrast in environments is substantiated by the chemistry of the mafic volcanic rocks. The Cradle Brook-Walton Brook Fault may represent in part the boundary between the Central and Eastern Volcanic belts of Giles and Ruitenberg (1977). If so, these two belts need not be facies equivalents as envisaged by these authors.

In addition to Precambrian rocks, previously unrecognized Cambrian rocks occur in the project area. Cambrian rocks in southern New Brunswick are considered indicative of a drastic change in the depositional and tectonic environments at the close of Precambrian time and have been associated with the transgression of the Iapetus Ocean. The existence of these rocks in the project area indicates that this transgression was more widespread than previously known.

Carboniferous and Triassic rocks occur in fault-bound blocks in Domains B and C and are of limited extent.

Several felsic and mafic plutons occur south of the Cradle Brook - Walton Brook Fault. Large intrusive bodies occur along the northern boundary of the project area, but are notably lacking in the rest of the area north of the fault. Two distinct groups of felsic intrusions occur south of the fault. One group, which consists predominantly of granite, granodiorite, monzodiorite, and low-K granite and forms elongated and rounded plugs, is chemically similar to the intrusive bodies to the north. The second group, which consists predominantly of more highly differentiated granite and leucogranite, occurs along major faults. Fine-grained felsic intrusions that consist of rhyolite and keratophyre also occur in the project area. Most of the felsic intrusive rocks are probably Precambrian in age.

Mafic intrusive rocks, mainly nonporphyritic and porphyritic gabbro and diabase, occur throughout the project area and are particularly abundant in the southern part. The gabbros occur as isolated stocks and plugs or are closely associated with the larger felsic intrusions. Diabase occurs in dykes of all dimensions that generally parallel the structural trend although cross-cutting relationships also exist. Chemically, the mafic intrusions exhibit iron enrichment trends and are classified as tholeiites. There is no consistent chemical distinction between the various types of mafic intrusions; they appear to have been derived from a similar source. Most of the mafic intrusions are affected by the deformation but a few diabase dykes cross-cut all tectonic fabrics and are post-Cambrian in age.

The deformational history of the project area is exceedingly complex and a detailed evaluation of structures is beyond the scope of this report. At least three major episodes of deformation occurred. The first major deformation, that is pervasively developed throughout the project area, resulted in intense cataclasis of most volcanic and sedimentary rocks and some of the intrusive rocks. Folds accompanying this deformation include shear folds of all orientations. There is evidence that this fabric overprints a locally developed, pre-existing fabric and that similar cataclastic fabrics were developed during or slightly later than the main pervasive fabric. The second major deformation resulted in the development of crenulations of the cataclastic fabrics and the development of second cleavage. The first and second deformational fabrics were deformed by kinks throughout the project area.

Numerous faults and fault zones that vary considerably in magnitude, occur throughout the project area. The most prominent fault structures are; a major southward-directed thrust fault that separates most of Domain A from Domains B and C, and a broad sinistral zone of wrench faulting that separates Domains B and C. The magnitude of displacement that occurred on the thrust fault is indeterminate. However, the nature of the rocks juxtaposed by the fault indicates that the magnitude is great. The age of movement is certainly post-Cambrian and it is probably Acadian. Several kilometres of displacement occurred along the faults in the zone of wrench faulting. This faulting is undoubtedly associated with the Hercynian Orogeny.

Copper and zinc sulphides and locally trace amounts of gold have been found in the project area. Chalcopyrite, bornite, malachite, chalcocite, sphalerite and small amounts of gold are widespread south of the Cradle Brook - Walton Brook Fault but occur at only a few localities north of the fault. South of the fault, metallic sulphides occur mainly in isolated quartz-calcite veins and in shear zones, but are also found disseminated in stratiform felsic volcanic and detrital sedimentary units. Metallic sulphides north of the fault are associated with felsic volcanic rocks.

Most exploration to date has been conducted in the northeastern part of the project area (the Quiddy River and Goose Creek prospects) and around the Vernon Mine near Martin Head. Fairly detailed work indicates that some high-grade metallic sulphides are associated with fault and shear zones in this area. Lower grade metallic sulphides occur in stratiform bodies. Other areas with significant amounts of metallic sulphides occur in Units 4 and 8. Both of these units warrant further investigation.

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